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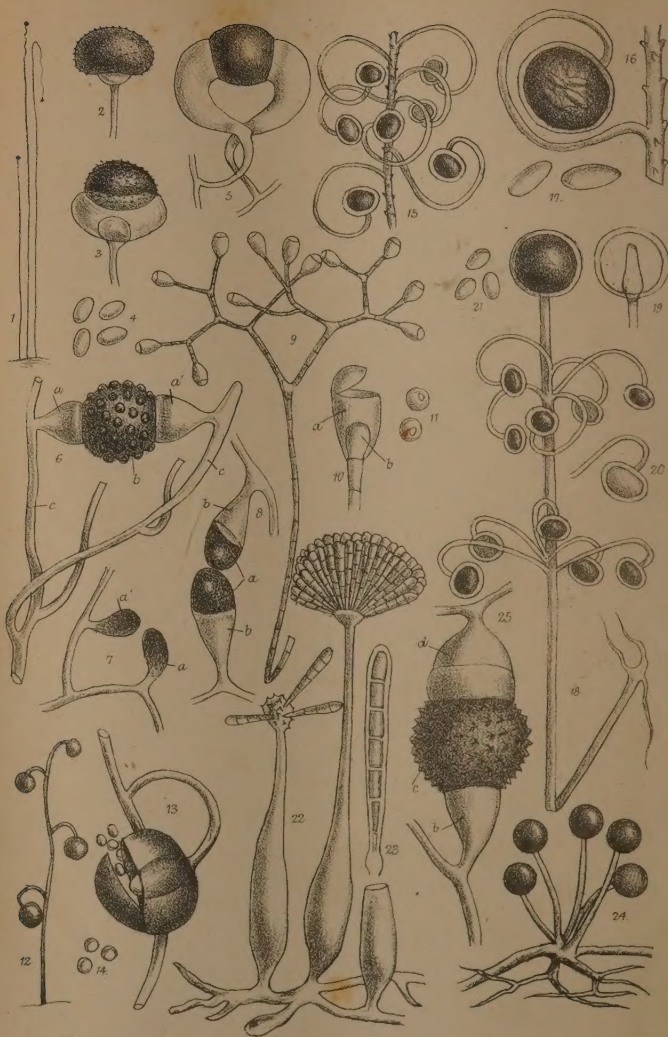
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# BRITISH FUNGI

PHYCOMYCETES AND ENTOMOPHYTES

GEORGE MANFRED

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*Teacher*

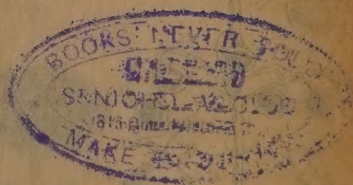
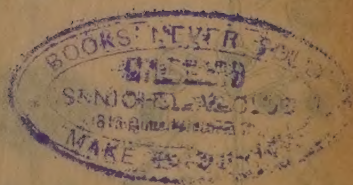


LONDON

L. BEEVE & CO.,

5, HINDUSTAN STREET, COVENT GARDEN

1891



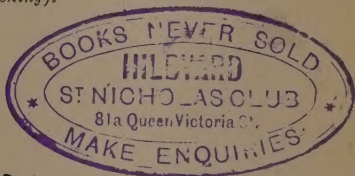
# BRITISH FUNGI.

PHYCOMYCETES AND USTILAGINEÆ.

BY

GEORGE MASSEE

*(Lecturer on Botany to the London Society for the Extension of University Teaching).*



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LONDON:

PRINTED BY GILBERT AND RIVINGTON, LD.,  
ST. JOHN'S HOUSE, CLERKENWELL ROAD, E.C.



## PREFACE.

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THE object of the present book is to bring up to date the British species of Fungi included in the divisions known as the *Phycomycetes* and the *Ustilagineæ*. Many species, and even genera belonging to the first-named division are new to our Flora, and careful search will undoubtedly reveal more new forms. The great interest in connection with such fungi, however, is not so much the discovery of new species, as a careful investigation into the life-history of forms already known. When this is done—and not before—it will be possible to speak of genera and species from a fairly safe standpoint. The introductory part of the present volume will give the reader an idea of the amount of investigation yet necessary, as proved by the directly opposed views of the best workers, on subjects that are of primary importance. It is hoped that other volumes dealing with the remainder of the fungi will not be long delayed.

GEORGE MASSEE.

*Kew*, 1891.



## DESCRIPTION OF THE FIGURES.

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### PLATE I.

FIG.

1. *Pilaira anomala*, group of plants, nat. size.
- 2, 3. Sporangia of same in different stages of development,  $\times 200$ .
4. Spores of same,  $\times 400$ .
5. Zygosporangium of same,  $\times 200$ .
6. *Sporodinia aspergillus*; *b*, zygosporangium; *a, a*, suspensors; *c, c*, mycelium,  $\times 250$ .
7. Formation of young zygosporangium of same; *a, a*, archicarpus,  $\times 250$ .
8. Formation of zygosporangium of same; *a*, one of the gametes or conjugating cells; *b*, one of the suspensors,  $\times 250$ .
9. Gonidial condition of same,  $\times 250$ .
10. Sporangium of same after dehiscence; *a*, sporangial wall; *b*, columella,  $\times 350$ .
11. Gonidia of same,  $\times 400$ .
12. *Circinella simplex*, entire fungus,  $\times 250$ .
13. Sporangium of same showing columella,  $\times 400$ .
14. Spores of same,  $\times 400$ .
15. *Helicostylum elegans*, portion of fungus,  $\times 200$ .
16. Sporangium of same,  $\times 400$ .
17. Spores of same,  $\times 750$ .
18. *Helicostylum nigricans*, entire plant,  $\times 250$ .
19. Optical section of sporangium of same showing columella,  $\times 250$ .
20. Optical section of lateral sporangium of same,  $\times 350$ .
21. Spores of same,  $\times 400$ .
22. *Syncephalis fasciculata*, portion of fungus,  $\times 200$ .

## FIG.

23. Single sporangium of same,  $\times 400$ .  
 24. *Rhizopus nigricans*, sporangiferous condition,  $\times 250$ .  
 25. Sexual condition of same; *a*, the large septate suspensor; *b*, the small aseptate suspensor; *c*, zygospore,  $\times 400$ .

## PLATE II.

26. *Monoblepharis sphaerica*, portion of fungus,  $\times 25$ .  
 27. Tip of a filament of same bearing an oogonium, *o*, and an antheridium, *a*; the oogonium has opened at the apex and contains an oosphere; the antherozoids are escaping from the antheridium,  $\times 800$ . (After Cornu.)  
 28. Portion of a filament of *Leptomitus brachynema*, bearing zoosporangia,  $\times 250$ .  
 29. *Mortierella polycephala*,  $\times 500$ .  
 30. Chlamydogonidia or acrogonidia of same,  $\times$ . (After Van Tieghem.)  
 31. *Achlya polyandra*; *a*, oogonium; *b*, oospores; *c*, antheridium,  $\times 300$ .  
 32. *Achlya racemosa*, tip of a fertile branch with an empty zoosporangium, *a*; *b*, the escaped zoogonidia forming a hollow sphere at the apex of the zoosporangium; lower down on the branch are two oogonia; *c*, oogonium; *e*, oospores; *d*, antheridia,  $\times 145$ . (After De Bary.)  
 33. *Thamnidium verticillatum*, erect sporangiferous branch; *a*, the terminal large sporangium; *b*, sporangiola borne on whorled lateral branches,  $\times 100$ .  
 34. Optical section of terminal sporangium of same showing columella, highly  $\times$ .  
 35. Optical section of lateral sporangiola of same, highly  $\times$ .  
 36. *Rhizidium Westii*, several plants parasitic on *Spirogyra nitida*, seen in optical section; the contents of the host are omitted,  $\times 300$ .  
 37. The same, parasitic on *Cladophora glomerata*; *c*, the thick stratified cell-wall of the host; *a*, upper, *b*, lower cell; *c*, rhizoids that are permeating the protoplasm of the host; *d*, sporangium; *d'*, sporangium ruptured and zoogonidia escaping,  $\times 1200$ .

## PLATE III.

FIG.

38. *Saprolegnia monoica*, tip of a fertile branch; *a*, oogonium; *b*, one of the perforations in its wall; *c*, antheridial branch,  $\times 400$ .
39. *Pythium De Baryanum*, portion of a specimen bearing terminal and intercalary gonidia,  $\times 200$ .
40. Fertile tip of branch of same; *a*, antheridium; *b*, oogonium; *c*, the oosphere which has just become rounded off,  $\times 400$ .
41. Gonidium of same germinating and producing a germ-tube which will develop directly into a new plant,  $\times 400$ .
42. *a*, gonidium of same germinating and giving origin to a zoosporangium, *b*, containing several zoogonidia,  $\times 400$ .
43. *Entorrhiza Aschersoniana*, forming swellings on the root of *Juncus lamprocarpus*, nat. size.
44. Spore of same,  $\times 1200$ .
45. *Peronospora parasitica*, an aerial gonidia-bearing branch,  $\times 300$ .
46. Gonidium of same,  $\times 750$ .
- 46a. Mature resting-spore of same,  $\times 500$ .
47. *Saprolegnia elongata*, branch bearing zoosporangia; *a*, *a'*, empty zoosporangia; *b*, *b'*, zoosporangia containing zoogonidia,  $\times 400$ .
48. Zoogonidium of same,  $\times 600$ .
49. Sexual condition of same; *a*, oogonium; *b*, oospores; *c*, antheridium, produced on a distinct branch,  $\times 400$ .
50. *Protomyces macrosporus*, pustules of mature spores on stem of *Ægopodium podagraria*, nat. size.
51. Resting-spores of same,  $\times 400$ .
52. *Tilletia decipiens*, spore,  $\times 1200$ .
53. *Tilletia tritici*, spore,  $\times 1200$ .
54. Spore of same germinating; *a*, promycelium bearing a tuft of promycelium spores, *b*, at the apex, some of which have "conjugated" in pairs,  $\times 460$ . (After Tulasne.)
55. Two promycelium spores of same that have "conjugated" and afterwards produced a secondary spore, *a*,  $\times 750$ . (After Tulasne.)

FIG.

56. Resting-spore of same germinating; *a*, promycelium; *b*, young promycelium spores,  $\times 460$ . (After Tulasne.)

## PLATE IV.

57. *Pilobolus crystallinus*, cluster of specimens; *a*, *a'*, sporangia; *b*, swollen apex of hypha; *c*, *c'*, drops of water exuded by the swollen portion of hyphæ,  $\times 100$ .
58. Spores of same,  $\times 400$ .
59. *Sorosporium scabies*, spore-cluster,  $\times 500$ .
- 59A. Single spores of same,  $\times 500$ .
- 60, 61. *Endodromia vitrea*, highly  $\times$ . (After Berkeley.)
62. *Chaetocladium Jonesii*, portion of a sporangiferous branch,  $\times 250$ . (After Berkeley.)
63. Sporangium, *a*, of same dehiscing and allowing the single spore, *b*, to escape,  $\times 500$ .
64. *Bremia lactucæ*, mature gonidium,  $\times 400$ . (After De Bary.)
65. Germinating gonidium of same,  $\times 200$ . (After De Bary.)
66. *Plasmopara nirea*, mature gonidium,  $\times 400$ .
67. Gonidium of same showing the protoplasm breaking up to form zoogonidia,  $\times 400$ .
68. Gonidium of same showing the zoogonidia in the act of escaping,  $\times 400$ .
69. Fully formed zoogonidia of same,  $\times 400$ .
70. *a*, section through the epidermis of a leaf of *Ægopodium podagraria*, showing a gonidium, *b*, of the same germinating on the surface and sending its germ tube, *c*, through a stoma into the tissue of the leaf,  $\times 400$ . (All after De Bary.)
- 70A. *Mucor lateritius*, erect sporangiferous hyphæ,  $\times 80$ .
71. Optical section of same,  $\times 400$ .
72. *Protomyces purpureo-tingens*, portion of a leaf of a seedling hollyhock showing the dark blotches caused by the parasite, nat. size.
73. Spores of same,  $\times 400$ .
74. *Spinellus fusiger*, sporangiferous erect hypha, showing

FIG.

- the branched creeping mycelium bearing short spinulose branches,  $\times 200$ .
75. Zygosporangium of same,  $\times 40$ . (After Van Tieghem.)
76. Optical section of sporangium of same,  $\times 200$ .
77. Spores of same,  $\times 400$ .
78. *Polyphagus Euglenæ*, zoogonidium showing a dark sphere of fatty matter and a nucleus,  $\times 550$ .
79. Young specimen of the same grown from a zoogonidium with a rhizoid attached to a resting *Euglena*, *e*,  $\times 350$ .
80. Zoosporangium of same with zoogonidia just formed, resting on the mother-cell (prosporangium), *a*, from which it originated; on the latter are three rhizoids,  $\times 400$ .
81. The same showing conjugation; *a*, the receptive individual; *b*, the supplying individual; *s*, the swollen end of the conjugating tube connecting *a* and *b* (this portion is the commencement of the resting-spore); *e, e*, the *Euglenæ* attacked by the fungus,  $\times 350$ .
82. A portion of the conjugating pair in Fig. 81,  $5\frac{1}{2}$  hours later than shown in Fig. 81; *b* and *s*, the same as before, *b* is now empty and *s* mature,  $\times 350$ . (All after Nowakowski.)

## PLATE V.

83. *Tilletia striiformis*, on leaf of *Glyceria fluitans*, nat. size.
84. Spore of same,  $\times 1200$ .
85. *Ustilago salveii*, spore,  $\times 1200$ .
86. *Urocystis colchici*, on portion of a leaf of *Colchicum autumnale*, nat. size.
87. Spore-clusters of same; *a*, central fertile cells; *b*, pale peripheral sterile cells,  $\times 400$ .
88. *Thecaphora hyalina*, spore-clusters,  $\times 400$ .
89. Isolated spores of same, showing the free portion of each spore warted; the flattened sides that are in contact when in the cluster are smooth,  $\times 400$ .
90. *Protonyces concomitans*, portions of hyphæ with intercalary and terminal spores growing in the cells of an orchid leaf, highly  $\times$  (After Berkeley.)



FIG.

91. *Diplanes saprolegnoides*, zoosporangium formed from the terminal branch of a filament; *a*, the aperture through which most of the zoogonidia have escaped, 250. (After Lietgeb.)
92. Zoogonidia of same,  $\times 250$ .
93. Sexual reproductive organs of same; *a*, oogonium furnished with perforations and containing seven oospores; *b*, antheridium.
94. *Thecaphora Trailii*, spore-cluster,  $\times 400$ .
95. Single spore of same,  $\times 1200$ .
96. *Ustilago grammica*, on stem of *Glyceria fluitans*, nat. size.
97. Spores of same,  $\times 400$ .
98. *Empusa muscae*, gonidiophores and gonidia in various stages of development; *a*, gonidiophore; *b*, gonidium,  $\times 200$ .
99. *Cystopus candidus*, showing the concatenate zoosporangia in various stages of development; *a*, gonidiophore; *b*, chains of zoosporangia;  $\times 400$ .
100. Zoogonidium of same,  $\times 750$ .
101. *Sphacelotheca hydropiperis*, longitudinal section through a sporophore of the fungus developed in the ovary of *Polygonum hydropiper*; *a*, perianth; *b*, wall of the ovary; *c*, spore-receptacle of the fungus composed of hyphae; *d*, columella; *e*, spore-mass; slightly  $\times$ . (After De Bary.)
102. *Dityuchus monosporus*, zoosporangium; the reticulation is due to the numerous empty cellulose walls originally enclosing the zoogonidia which remain in the zoosporangium; to the left of the zoosporangium is seen a free zoogonidium with its two cilia,  $\times 250$ .
103. Oogonium of same containing a single oospore,  $\times 400$ .
104. Oogonium of same clasped by an antheridium,  $\times 400$ . (After Lietgeb.)

## PLATE VI.

105. *Aphanomyces stellatus*, fertile tip of a hypha converted into a zoosporangium, showing the single row of zoogonidia in the act of formation,  $\times 400$ .

FIG.

106. The same, showing the escaping zoogonidia forming a cluster at the apex of the zoosporangium,  $\times 400$ .
107. Zoogonidia of same,  $\times 750$ .
108. Oogonia and antheridia of same,  $\times 390$ . (After De Bary.)
109. *Sorosporium saponariae*, cluster of spores,  $\times 520$ . (After Woronin.)
110. Spore of same germinating,  $\times 520$ . (After Woronin.)
111. *Thecaphora hyalina*, spore-cluster, one of the spores germinating,  $\times 520$ . (After Woronin.)
112. *Tubercinia trientalis*, a group of gonidiophores emerging into the air through the stoma of a leaf of *Trientalis europaea*; *a*, *a'*, haustoria on the mycelium; *b*, guard-cells of the stoma;  $\times 520$ . (After Woronin.)
113. Spore-cluster of same, some of the spores have germinated; *a*, promycelium; *b*, primary sporidia;  $\times 520$ . (After Woronin.)
114. Primary sporidia of same giving origin to, *a*, *a*, secondary sporidia;  $\times 520$ . (After Woronin.)
115. Primary sporidium, *a*, of same that has given origin to, *b*, a secondary sporidium, the latter in turn has produced a tertiary sporidium, *c*,  $\times 520$ . (After Woronin.)
116. *Etyloma ranunculi*, gonidiophores emerging into the air through a stoma of the leaf of *Ficaria ranunculus*,  $\times 500$ .
117. Resting-spores of same in various stages of development,  $\times$  Zeiss J. (After Ward.)
118. *Doassansia alismatis*, portion of a fructification; *a*, sterile cells of fungus arranged in a palisade-like manner and forming a receptacle; *b*, mass of fertile spores;  $\times 500$ .
119. Spore of same germinating; *a*, promycelium; *b*, apical group of primary sporidia, highly  $\times$ . (After Cornu.)
120. *Ustilago tragopogi*, resting-spores germinating; *a*, *a*, primary sporidia produced by the promycelium,  $\times 460$ . (After Tulasne.)

## PLATE VII.

FIG.

121. *Phytophthora infestans*, gonidiophore growing into the air through a stoma on the under surface of a potato leaf,  $\times 150$ .
122. Mature zoosporangium of same,  $\times 400$ .
123. Zoosporangium of same showing the protoplasm breaking up into zoogonidia,  $\times 400$ .
124. Zoogonidia of same,  $\times 400$ .
125. A zoogonidium of same, after having retracted its cilia and assumed a spherical form, germinating,  $\times 400$ .
126. A gonidium of the same germinating; the gonidium is morphologically similar to a zoosporangium, but differs in giving origin to a germ, tube directly, instead of producing zoogonidia,  $\times 400$ .
127. *Cystopus candidus*, portion of mycelium bearing an oogonium, *a*; *b*, oosphere, which after fertilization secretes a thick, warted wall; *c*, antheridium; *d*, an immature oogonium,  $\times 650$ .
128. Mature oosphere or resting-spore of same showing escape of zoogonidia; *a*, exosporium; *b*, endosporium; *c*, free zoogonidia; *d*, remains of the wall of the oogonium,  $\times 650$ .
129. *Peronospora parasitica*, showing a portion of mycelium parasitic in the tissues of *Capsella bursa-pastoris*; *a*, branch mycelium running between the cells of the host and sending off haustoria into the cells, *a. a*; the mycelium is much constricted at the points where it pierces the cell-wall,  $\times 650$ .
130. *Chetocladium Brefeldii*, portion of a much-branched sporangiophore bearing monosporous sporangia,  $\times 130$ . (After Van Tieghem.)
131. *Pilaira dimidiata*; *a*, mature sporangium,  $\times 120$ ; *b*, a plant with a young sporangium,  $\times 80$ ; *c*, spores,  $\times 500$ ; *d*, columella,  $\times 120$ . (After Grove.)
132. *Tuberculina persicina*, section through a sorus,  $\times 120$ .
133. *Graphiola phœnicis*, section of fungus growing on a leaf of *Phœnix dactylifera*; *a*, sterile tuft of hyphæ that spring from the base of the hymenium after the spores are formed,  $\times 200$ .

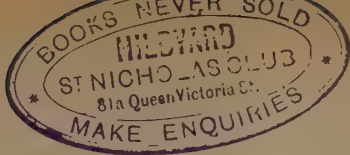
134. Basidium of same bearing numerous small spores,  $\times$  650.

PLATE VIII.

135. *Protomycites protogenes*, W. Sm., single sporangium, preserved in the rootlet of a fossil *Lepidodendron* from the coal-measures,  $\times$  400. (After W. G. Smith.)
136. *Peronosporites antiquarius*, W. Sm., numerous sporangia and mycelium in the vascular axis of a *Lepidodendron* from the coal-measures,  $\times$  400. (After W. G. Smith.)
137. *Peronosporites antiquarius*, W. Sm., in *Lepidodendroid* bark from the coal-measures, Halifax,  $\times$  320. (After Williamson.)

## ERRATUM.

Page 47, third line from bottom, for *fungus* read *lichen*.



# BRITISH FUNGI.

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## GENERAL INTRODUCTION.

### MORPHOLOGY.

WHAT is a fungus? This question naturally suggests itself as first claiming attention in a work treating exclusively of the fungi, yet in reality the answer can only be clearly understood after some insight has been gained of the peculiarities of structure and mode of life of the fungi as a group, and also of their origin and relationship with other groups of the vegetable kingdom, because a definition of any group consists of the most pronounced morphological and physiological peculiarities possessed generally by its component members; nevertheless, one or two of the leading characters may be given at this stage. *Chlorophyll*, the green colouring matter so general in the vegetable kingdom, is entirely absent from fungi, and as chlorophyll is an indispensable factor in enabling plants to utilize inorganic matter as food, it follows that fungi cannot assimilate inorganic food, but are entirely dependent on organic matter for food, and may be divided into two groups, depending on the condition in which organic matter is used as food; those that obtain their food material from dead organic matter are called *saprophytes*, such are the fungi growing on

rotten wood, and also the common mushroom, whereas those that grow upon or within living animals or plants, and from whose tissues their food is derived, are known as *parasites*; the smut of wheat, hop mildew, potato disease, and "muscardine," or the silkworm disease, are examples of the latter class. Connecting links between the two conditions occur, some species possessing the faculty of existing as either parasites or saprophytes, and others are saprophytes during one period and parasites at another. Fungi belong to the group of plants known as *Cryptogams*, hence, if we speak of fungi as *Cryptogams without chlorophyll* we shall embody the most important characters of the group; the finer distinctions that separate other groups of cryptogams not possessing chlorophyll, as the *Bacteria* and the *Myxogastres*, will be better understood at a later stage.

The tissues of fungi, however compact, consist of rows of cells called *hyphæ*; these hyphæ may consist of very long, continuous cells without transverse walls or *septa*, or transverse septa may be present, when the hypha consists of a large number of superposed cells in a single row. Hyphæ may be simple or branched, and not unfrequently when two distinct branches meet they grow together, the walls being dissolved at the point of contact, and the contents of the two branches mingle; in some cases a complicated network is thus produced, or H shaped arrangements occur when two parallel hyphæ are united by a branch from one uniting at its point with the other. A peculiar structure resulting from the amalgamation of originally independent parts, forming what are known

as *clamp-connections*, originates as follows,—in a transversely septate hypha a small branch originates just below a septum, grows out for some distance, then bends until its tip comes in contact with the wall of the hypha just above the septum below which it sprung, the walls become absorbed at the point of contact, the result being that the loop formed by the branch has opened a free communication between the cavities of the two cells of the hypha separated by the septum. Clamp-connections are highly characteristic of the group of fungi known as the *Basidiomycetes*, but are also met with in at least one genus belonging to the *Hyphomycetes*. The object of this arrangement is not known, but Professor Marshall Ward has described a case<sup>1</sup> where the hyphæ form a dense, irregular network due to the amalgamation of originally distinct branches, and has demonstrated the remarkable fact that this blending is not confined to those points where two hyphæ happen to come in contact in the ordinary course of growth, but that distinct branches are actually drawn out of their original course through nearly a right angle by another branch for the purpose of effecting a union, and consequently open communication between the two branches. This attraction is considered by the author to be due to the presence of a ferment-substance present in the cells, and as to the object, it is suggested that it possibly serves to nourish the whole more equably, or to effect the equal distribution of certain substances produced in the cell-contents. The first hyphæ produced on the germination of the

<sup>1</sup> A lily disease, *Ann. Bot.* vol. ii. pp. 319-378.



spore form the *mycelium*, in fact this name is rather vague, but is generally understood to refer to the hyphæ concerned with vegetative work, and is either buried in the substance from which the fungus obtains its food supply, as in the common mushroom and most mushroom-like fungi, or forms a more or less dense layer on the surface, as in many moulds, sending branches down into the substance it rests upon for the purpose of absorbing food. In most cases the hyphæ penetrating the matrix are of the ordinary filamentous kind, but sometimes, more especially in the minute fungi parasitic on living plants, the hyphæ that enter the matrix become more or less expanded at the tip, forming *haustoria* or suckers, which are supposed to answer the double purpose of firmly fixing the fungus and absorbing food.

When young and actively growing, the hyphæ have very thin, colourless cell-walls, which usually give a cellulose reaction, becoming violet when treated with sulphuric acid and iodine, or a clear blue with iodine alone, but when the hyphæ are old this reaction is rarely, if ever, obtained without special and prolonged preparation, hence the name "fungus-cellulose" given by De Bary.<sup>2</sup> With age the walls of the hyphæ frequently become coloured and thickened to such an extent that the *lumen* or cavity is almost filled up, and in some cases the thickened wall shows distinct *stratification*, as pointed out by De Bary<sup>3</sup> in the inner layer of the exoperidium of

<sup>2</sup> Fungi, Mycetozoa and Bacteria, English Edition, pp. 8 and 13.

<sup>3</sup> Tom. cit. p. 12.

*Geaster hygrometricus*, where the wall in transverse section is seen to consist of from three to five layers or *lamellæ*. In many fungi the thickened walls of the hyphæ become partly dissolved on the outside, and form a gelatinous mass when moist, becoming horny and rigid when dry. This idea is carried to the extreme in *Tremellinæ*, where a section under the microscope presents the appearance of a densely interwoven mass of very fine threads imbedded in a homogeneous gelatinous substance. The apparent fine threads are the very much reduced cavities of the interlaced hyphæ containing a finely granular substance, the gelatinous matter consists of the dissolved cell-walls that have completely lost their individuality and form a homogeneous mass. Fine *pits* are present in the walls of certain hyphæ in the genus *Lycoperdon*, and De Bary states that in the mould called *Dactylium macrosporum*, there is a large pit in the centre of the thick transverse septa similar to what is found in the transverse septa of the *Florideæ* or red sea-weeds. It has already been stated that the tissues of fungi consist of more or less parallel or intricately interwoven simple or branched hyphæ, and that increase in size depends on the formation of new cells at the tips of the hyphæ only, and this statement generally holds good, but cannot be universally applied, as in many well-known instances we get a tissue formed from a single cell dividing in different planes as in the case of flowering plants, and consequently producing true fundamental or cellular tissue. In many fungi the mycelium becomes concentrated at certain points into a solid mass called a *sclerotium*;

these sclerotia are met with in many different families, and vary in size from a mere point to that of a cricket ball, and in some instances are very much larger. In a species of *Boletus* found in West Australia the underground mycelium forms a hard sclerotoid mass, of a bright yellow colour, extending continuously for many square yards, and causes great inconvenience, having to be broken up with a pick-axe. Sclerotia may be looked upon as concentrations of reserve material manufactured by the mycelium, and often possesses the power of remaining dormant for a long period, eventually under favourable conditions producing spore-bearing structures, which not unfrequently differ very considerably in appearance and structure from those previously produced by the mycelium forming the sclerotium. When dry, sclerotia become hard and woody in texture, and on examining a thin section under the microscope are found to be composed of cells of various forms closely compacted together; but it is not difficult in general to trace distinct hyphæ here and there, and the apparent normal cellular-tissue appearance is in most cases due to the fact that the component hyphæ are so inextricably interwoven to form the solid mass, that in a section, taken in whatever direction, most of the hyphæ are cut in a direction more or less at right angles to the axes of growth, which results in a section made up of irregularly circular or elliptical cells. Nevertheless, in some instances a sclerotium is built up after the manner of true cellular tissue, and not from long, interwoven hyphæ. A minute black mould called *Heterosporium aspratium*, common on the leaves of

various liliaceous plants, has its mycelium ramifying through the tissues of the leaf, and sends spore-bearing branches into the air through the stomata; this takes place during the summer, and in the autumn when the leaf is fading, small sclerotia are formed by the mycelium in its interior in the following manner,—one of the cells of a hypha becomes larger than the rest, and is then divided by two septa, in planes at right angles to each other, into four cells; this process is repeated with more or less regularity in each of the daughter-cells, and this process of division is repeated until a mass of tissue is formed resulting from the division of cells by planes lying in different directions; sometimes two or more adjoining hyphal cells divide in a similar manner to form an irregular, elongated sclerotium. Many-celled spores are frequently formed in a similar manner.

The mycelium, usually after devoting a longer or shorter period of time to *vegetative* work, by which is meant, work connected with the well-being of the individual, and not directly concerned with reproduction, or continuation of the species in time, gives origin to a more or less complicated arrangement of hyphæ, for the special purpose of producing reproductive organs, and known collectively as the *sporophore*. As illustrations, the “spawn” or underground mycelium of the common mushroom is the vegetative portion of the fungus, whereas the stem, cap and gills together form the sporophore. Again, in the greenish-blue mould common on jam, bread, &c., the thin felt-like layer resting on the surface of the substance, along with the hyphæ sent down into the matrix, form the

vegetative part, and the erect hyphæ bearing chains of spores at their tips are the sporophores. From the above examples it will be seen that the sporophore presents great variety in form and structure, consisting in the one instance of a single erect hypha bearing a few spores at its summit, whereas in the other, dense, differentiated tissues enter into its composition. The sporophore is the part that is popularly considered as constituting the entire fungus, the vegetative portion, as already stated, being usually hidden in the substance upon which the sporophore appears. From what has already been stated, it will be seen that division of labour is well marked in fungi, as illustrated by the presence of mycelium and sporophore, but it is important to remember that this division is not so strongly defined throughout the fungi as in the examples given. In the *Saprolegniae*, a group of microscopic fungi met with in the tissues of plants or animals, the thin hyphæ ramify in the tissues of the host, and eventually form reproductive bodies, the equivalents of sporophores, from single terminal or intercalary cells of the mycelium. Now this arrangement does not quite harmonize with the conception of sharply defined vegetative and reproductive parts as illustrated by the gill-bearing fungi and their allies:

From a broad point of view, the characters that separate plants from animals are; (1), permanent cell-walls, composed of cellulose, at least when young; (2), the presence of chlorophyll, which enables plants to feed on inorganic food. It is well known that certain plants belonging to widely separated natural

orders, have degenerated so far from the ancestral stock as to have lost the power of forming chlorophyll, and in consequence, like the fungi, have become parasites or saprophytes, the bird's-nest orchis, *Neottia nidus-avis*, and toothwort, *Lathræa squamaria*, are examples, but in most such cases, these degenerate species still retain the same general structure, so that there is but little difficulty in consigning them to their proper orders, although in some instances these phanerogamic departures from the typical stock have become so modified as to present but slight affinities with any of the normal groups. The fungi, in like manner, appear to have descended from chlorophyll-producing ancestors, but such ancestors were very much lower down, or nearer the starting-point of plant life, than flowering plants, and are represented at the present day by the simple green algæ furnished with sexual organs, illustrated by such genera as *Vaucheria*. The *Saprolegniæ*, mostly aquatic fungi, and the *Peronosporæ*, inhabiting the tissues of living plants, may be considered as illustrations of forms near the starting-point of the fungi proper, and omitting for the moment the presence of chlorophyll in the one case, and its absence in the other, the above-mentioned algal and fungal forms present many important morphological features in common. In both there is the same long, irregularly-branched vegetative portion, in both the tips or interstitial portions become swollen into a more or less globose receptacle or *oogonium*, the female organ of reproduction, into which the protoplasm becomes aggregated and retained by the formation of septa

across the tube. This oosphere is fertilized by a small organ or *antheridium* produced in close proximity to the oogonium, or on a distinct branch, depending on the particular species. It is very important to bear in mind that the above account is not intended to convey the idea that fungi actually originated from the algal genus *Vaucheria* and allied forms, but simply to show that at the points indicated the homologies between algæ and fungi are very pronounced.

In the degenerate forms of flowering plants already mentioned, we find several distinct starting-points, as in *Orchidaceæ*, *Scrophulariaceæ*, *Balanophoreæ*, &c., and although agreeing in the common feature of having their power of developing chlorophyll arrested, yet these starting-points of new plant ideas must have been separated by long intervals of time, inasmuch as the aberrant members of the two first-mentioned orders would still be typical members of their respective orders if furnished with chlorophyll, whereas, in the last order, the species have become so much modified that they are not in close touch with any known order of chlorophyll-bearing plants, a fact implying a long period of time since they broke away from their normal ancestors; because it must be remembered that there is no evidence in favour of the idea that plants without chlorophyll originated as such, whereas the evidence in favour of the idea that all plants without chlorophyll have descended from chlorophyll-producing ancestors is very strong.

Judging from the case of the fungi, there is no reason why the side issues of flowering plants, characterized by absence of chlorophyll, should not become

so thoroughly differentiated from the parent stock, as to constitute a distinct group, phanerogamic fungi.

In like manner, it is not necessary to assume only one point of departure for the fungi from the algæ, but the close agreement between the *Saprolegniæ* and certain algæ indicates the origin of the fungi, and shows also that between the two examples given the point of divergence is not wide. It is observable in almost every instance of a marked departure from a typical group, that the earliest departures remain stereotyped at a certain stage of development as a group, characterized by features partly their own and partly those of their ancestors; connecting-links in fact. Certain elastic members of this first group in turn develop new features, and where the new departure is able to hold its ground in the struggle for existence, this process of evolving new morphological and physiological factors, a process generally contemporaneous with the obliteration of the original characteristics of the stock from which the new type originated, is repeated, until eventually a group of organisms is produced possessing strongly marked features in common, and only in touch with the group from which it evolved in the possession of those characters common to all plants.

In illustration of the above, it may be mentioned that in those sections of fungi, of which the mushroom and puffball are characteristic, there is not the remotest indication, morphologically or physiologically, not even in the earliest phase of development, of any affinity with the algæ, and it is only by means of tracing the origin of these terminal groups of fungi



from others lower in the scale of fungal differentiation that their true origin and sequence can be determined. From what has been said respecting the evolution of the fungi from the algæ, and also of the sequence from the most highly differentiated to the primitive group of fungi, there is the danger on the part of the reader of assuming that the origin and sequence of development of the fungi is fairly complete. To guard against any misconception, it is important to state clearly that such is not the case; it is generally admitted that the fungi are of algal origin, and further, that the main divisions of fungi are connected with each to such an extent that the idea of independent starting-points is not suggested; but it must be remembered that each of the main sections into which fungi are naturally divided, is composed of several smaller sections, and the sequence of origin and affinity between these minor sections are yet far from being settled. We may conclude this portion of the subject by stating that the most fascinating branch of biology—embodied in the term (life-history)—can alone indicate the required evidence for a satisfactory solution of the affinities between the various sections.

The individuality of the fungal group cannot be briefly expressed, but the two most prominent modifications in the relative proportion and functional value of parts constituting the *Phycomycetes*, which stand near the base or starting-point of the group, may be pointed out as the prime factors in connection with this individuality.

In the *Phycomycetes*, to which the *Saprolegniæ* and *Peronosporæ* belong, the sexual mode of reproduction

is very general, whereas the asexual or gonidial method is often by no means pronounced, and in numerous cases is not known to exist at all. It has already been stated that the sexual organs of reproduction in the *Peronosporæ* are promiscuously scattered amongst the cells of the vegetative hyphæ, and do not originate from differentiated hyphæ constituting a sporophore.

In the gill-bearing fungi and the puffballs, which are respectively typical of the extremes of differentiation from primitive algal-like fungi, the sexual mode of reproduction is entirely absent, the asexual, gonidial form alone remaining, and produced on a very highly specialized sporophore, the mycelium being functionally and morphologically unchanged during the evolution of the reproductive portion. The above statements, pointing to what changes the individuality of the group of fungi are due, may be summarized as follows:—

1. The complete obliteration of the sexual mode of reproduction, so very conspicuous in the lower or algal-like fungi.
2. The excessive development of the asexual mode of reproduction, which is either entirely absent or of secondary importance in the lower fungi.
3. The gradual development of a highly complex sporophore, which usually constitutes the great bulk of the individual, whereas in the algal-like fungi the sporophore is barely, if at all, differentiated from the vegetative portion.

From the above it will be seen that differentiation has been almost entirely confined to the reproductive

portion, the vegetative part being as primitive in the *Agaricini* or gill-bearing fungi as in the earliest known algal-like fungi.

The various types of sporophore, along with the terms used in connection therewith, will be described under the various sections.

In the more highly differentiated types of sporophore, *laticiferous hyphæ* are frequently present, and more especially in certain sections of the gill-bearing funguses, where they form dense, anastomosing wefts in the tissues of stem, *pileus* or cap, and *lamellæ* or gills. These laticiferous hyphæ originate as lateral branches from the ordinary hyphæ of the sporophore when the latter is very young, their walls remain very thin, and transverse septa are present at first, but are eventually absorbed, at least this takes place in many species of *Lactarius*, where laticiferous hyphæ are especially numerous and well developed, although in *Lactarius torminosus* I have not succeeded in finding transverse septa at any period of development. The *latex*, or contents of laticiferous hyphæ, consists of very fine granules suspended in a watery fluid, and is generally colourless while in the hyphæ, but when liberated and exposed to the air frequently changes colour at once, becoming lilac in *Lactarius uvidus*, golden-yellow in *Lactarius chrysorrhæus*, and reddish in *Lactarius acris*; however, in the majority of species the latex is dense and white when liberated, and is often described as "milk" by systematists. In *Lactarius deliciosus* the latex becomes orange-red while yet contained in the hyphæ. In some species, as *Lactarius rufus*, the milk is intensely hot and pungent, the

minutest portion applied to the tongue producing an irritating tingling sensation that continues for some time. This peculiar property appears to be due to some chemical change in the latex caused by contact with the air and probably with oxygen, as when a drop is placed on the tongue, contact with air intensifies the burning sensation, whereas if, after rubbing the latex into the tongue, the part is covered with oil or butter, no tingling sensation is felt on exposure to the air. In other species the latex is perfectly mild, as in *Lactarius pallidus*. In most species of *Lactarius* the latex is so copious that, when the slightest wound is made, it flows out in considerable quantities. In *Russula*, a genus closely allied to *Lactarius*, laticiferous hyphæ are also very abundant, but the latex is denser and does not escape in the liquid form when the tissue is broken, but the burning sensation produced when a minute portion of the tissue is placed in contact with the tongue is in many cases far more intense than in the genus *Lactarius*; *Russula cutefracta* stands pre-eminent in this respect. *Russula* contains some of the most poisonous species of fungi, but there is no necessary connection between the pungency of the latex and the poisonous property; *Russula emetica* is a deadly poison, but is mild to the taste. Nothing satisfactory is known respecting the functions of latex. For the purpose of studying the laticiferous system, it is advisable to allow the specimen to dry for three or four days, as, if sections are cut when fresh, especially in the genus *Lactarius*, the whole of the latex escapes, whereas if it is allowed to dry, the watery portion of the latex evaporates, and the

granular portion remains and does not escape on cutting. Placing the whole fungus in alcohol or methylated spirit for some time produces the same effect. If sections thus prepared are stained with a solution of eosin, to which a drop or two of acetic acid has been added, the granular contents of the laticiferous hyphæ become deeply stained.

*Nuclei* have for some time past been proved to be present in the cells of fungi, but until quite recently this proof depended mainly on the fact that nuclei become more deeply stained than the remainder of the protoplasm, and so in the case of the vegetative portions of fungi, where the nuclei are minute and not possessed of any very pronounced morphological features, this evidence was scarcely satisfactory, because minute coagulations of protoplasm often become deeply stained, and are thus liable to be mistaken for nuclei. Recently, however, Wager has shown<sup>4</sup> that numerous nuclei are present in both vegetative and reproductive parts of a minute fungus, called *Peronospora parasitica*, very common as a parasite in the tissues of various cruciferous plants. In addition to the evidence afforded by staining, the author has shown that the nuclei divide by a process of karyokinesis, in a manner comparable to what takes place in the division of the nucleus in flowering plants. The following process was found to furnish the best preparations for observing the presence and various phases of division of the nuclei. The fresh tissues of the Shepherd's Purse infected with the

<sup>4</sup> Observations on the structure of the nuclei in *Peronospora parasitica*, &c. Ann. Bot. vol. iv. pp. 126-147; pl. 1.

fungus were cut into small pieces and placed at once in absolute alcohol, where they remained until thoroughly penetrated; sections were then cut, and afterwards stained in very dilute solution of Kleinenberg's hæmatoxylin in water. The sections were left in this solution until considerably overstained, and then placed in a dilute solution of acid alcohol made by adding a few drops of strong hydrochloric acid to a beaker of 70 per cent. alcohol. The sections were then washed successively in 70, 90, and 100 per cent. alcohol, then transferred to turpentine until quite clear and transparent, and finally mounted in Canada balsam.

It is true that Wager's sections were cut with a Cambridge ribbon-section-cutting-machine, and in many cases were only about  $\frac{1}{8000}$  of an inch in thickness, yet in repeating the work along the lines given above, I find that very good preparations can be obtained even when the sections are cut by hand with a razor.

*Calcium oxalate*, in the form of needle-shaped crystals, regular quadrate octahedra, or minute amorphous particles, is of very frequent occurrence in fungi, forming thin incrustations or a pulverulent, glistening layer on the sporophore, in the tissues, or sometimes on the strands of mycelium. This lime is probably taken up by fungi as *calcium nitrate* in solution, and the fact that calcic oxalate is most abundant in species of fungi that grow on dung, supports this idea. So long as the calcic oxalate is in the cells it is held in solution, and is conveyed to the surface by water, which, during the active period of growth, escapes from the ordinary hyphæ, or

sometimes from specialized portions of the sporophore, in considerable quantities. When outside the cell-wall, the water evaporates, leaving the calcic oxalate behind in the solid form. This deposit is most abundant, as would be expected, on young sporophores, being washed off by rain or dew as the fungus becomes old. A very common, densely tufted, gill-bearing fungus, with a fluted, ochraceous pileus, called *Coprinus micaceus*, derives its specific name from the dense layer of sparkling crystals of oxalate of lime covering the young pileus, which resembles a dusting of mica or crystallized sugar. As to whether calcium oxalate is of any definite use to fungi is not known; it may possibly assist in some way in connection with *metabolism*, or the transport of formative material from the mycelium to the sporophore during its growth.

The texture of the tissue forming the sporophore varies considerably in different groups, and in many cases is very different in different species belonging to the same genus. In the small, short-lived, gill-bearing fungi the stem generally consists of rows of hyphæ more or less parallel to its length, but at the same time more or less branched and intertwined. The hyphæ as a rule are more compact and thicker-walled towards the periphery, and usually disappear in the centre with age, leaving the skin more or less completely hollow. The surface of the pileus is also more compact than the inner portion or "flesh," and very frequently presents a smooth and polished appearance, due to the gelification of the walls of the superficial hyphæ, which afterwards stick together and form a

“skin,” which in dry weather forms a more or less cartilaginous layer, and when wet can often be peeled off as a slimy pellicle. The slime that covers the pileus of many fungi in wet weather, often in such quantities as to trickle away in drops, is also due to the complete gelification or melting of the external hyphæ. In perennial fungi, frequently spoken of as woody fungi, on account of the hardness of their tissues, the walls of the hyphæ usually become much thickened, and at the same time coloured and cemented together by the partial gelification of their walls, which on again hardening form a tissue as hard and firm as the hardest wood. Such structures are common in the large group known as the *Polyporeæ*. The above account covers the most usual changes taking place in the sporophore for the purpose of giving greater strength to the structure, but I have described elsewhere<sup>5</sup> a very remarkable differentiation in the tissue of the sporophore, for the purpose of giving additional strength, met with in a few species of *Polyporus*. In *Polyporus pisochapani*, a fungus having a stem four or five inches long and about half an inch thick, and a pileus about three inches across, the tissue in the young condition is homogeneous and pliable, just a little denser towards the outside, but as the fungus approaches maturity, the tissue of the stem and pileus undergoes a remarkable differentiation as follows: a thin zone of tissue just within the circumference of the stem becomes sharply defined by having the walls of the hyphæ thickened by additions

<sup>5</sup> On the differentiation of the tissues in Fungi, Journ. Roy. Micr. Soc., 1887, pp. 205-208, pl. 1.



to the inside to such an extent that the *lumen* or cavity is almost obliterated. This is accompanied by partial gelification, and subsequent cementing together of the hyphæ into a compact woody mass. The result of this differentiation is a thin hollow cylinder of rigid tissue extending throughout the length of the stem and just within the circumference, the central portion of the stem consisting of unmodified hyphæ. At the apex of the stem the woody ring expands into the pileus in the form of numerous tapering rays of the same consistency as the stem cylinder, and modified from the original soft tissue of the pileus. When the soft portions of the pileus and stem decay, the hardened portion described above remains in the form of a hollow stem with a trumpet-shaped terminal portion formed of radiating tapering ribs. A few other allied species of *Polyporus* present a similar marked differentiation of tissues in the sporophore.

*Coloration* in fungi is often very pronounced. De Bary considers that the colours are as a rule present only in the substance of the walls of the hyphæ, and not in the cell-contents, and more especially after the walls have undergone some modification, as in the deep red of the pileus of the poisonous fly agaric, *Amanita muscarius*, where the brilliant colour is confined to the thin gelatinized layer on the surface of the pileus. In the genus *Calostoma* again, the bright vermilion colour of a specialized zone of tissue in the sporophore is produced by the disintegration of the hyphæ, which results in a dry powdery mass. Light appears in some cases to be an indispensable factor in

the development of colour, for in many of the brilliantly coloured species of *Russula*, where a leaf has stuck to the viscid surface of the pileus at an early stage of development, the covered portion remains colourless.

In many of the gill-bearing fungi, where the tints are purest and most brilliant, the colours bleach and disappear as the fungus becomes old. The green tints sometimes present in fungi are not due to chlorophyll. The green colour of the wood used for "Tunbridge ware" was at one time supposed to be due to a small fungus, *Peziza æruginosa*, growing on the wood, but De Bary considers the question undecided, and suggests that it ought not be difficult to settle the question by artificial cultivation of the fungus. The use of colour to fungi is not obvious in most cases, and may possibly be the unavoidable result of metabolism and not produced for a specific object. But this explanation, if correct, is not true of all, as in the *Phalloideæ*, a group including the common stinkhorn. Brilliant colours in combination with a sweet sugary substance, and usually a very powerful odour, serve to attract flies, which are supposed to aid in the dispersion of the spores.

A very remarkable instance of coloration is seen in many species belonging to the genus *Boletus*. In *Boletus luridus*, a species not uncommon in Britain, the tissue of the pileus and stem is yellow in the uninjured state, but the instant it is broken and exposed to the air, assumes a deep indigo-blue colour; this colour soon fades, and the tissue remains of a dingy greyish-yellow tint. Schönbein's explanation of this

phenomenon is summarized as follows by De Bary.<sup>6</sup> "Schönbein has carefully examined this phenomenon, and finds that it is a substance capable of being extracted from the fungus by alcohol, and probably of a resinous character which turns blue in the air. The blue colour appears in the alcoholic solution under the same conditions as it does in a solution of guaiac-resin, and since it has been proved that the colour is produced in the latter by combination with ozonized oxygen, Schönbein assumes a similar cause of the blue colour in the fungus. The alcoholic extract from the *Boletus* does not by itself become blue when exposed to the air ; there must therefore be another substance contained in the fungus, which ozonizes the oxygen of the atmosphere, and then effects a combination with the resin, giving off the oxygen to it in the state of ozone. Phenomena of a similar kind, observed in other cases, confirm this conjecture. Thus both the tincture of guaiac and the alcoholic extract of *Boletus* turn blue at once, if they are allowed to fall in drops on the fresh tissue of some of the Agarici which do not themselves turn blue, especially *Agaricus sanguineus*. The watery juice of *Agaricus sanguineus* squeezed out from the plant and filtered, produces the blue colour at once in both tinctures. From these facts it may be concluded that a number of fleshy fungi contain a substance soluble in water, which absorbs oxygen and gives it up to other bodies in the state of ozone. The Boleti which turn blue contain this substance, with another resinous sub-

<sup>6</sup> Vol. cit., p. 15.

stance, which, like guaiac-resin, is turned blue by ozone."

*Starch* is absent from the tissues of fungi, but Errera has shown<sup>7</sup> that *glycogen* is present often in considerable quantity in the vegetative and reproductive parts of fungi. Glycogen has the same chemical composition as starch ( $C_6H_{10}O_5$ ), and is considered by Errera to be of the same value in the nutrition of fungi as starch is in plants possessing chlorophyll, but this point is not definitely ascertained. Glycogen may be distinguished from protoplasm by being more highly refringent and glistening, and by its behaviour when treated with iodine. If sections of tissue are slightly warmed in a dilute solution of iodine (water 45 grm., potassic iodide 0.3 grm., iodine 0.1 grm.), those parts containing glycogen became reddish-brown or violet-brown; the colour becomes paler when heated to between  $50^{\circ}$ — $60^{\circ}$  C., and returns on cooling. Glycogen can be well seen in the asci of many species of *Peziza* after the protoplasm has been used up in the formation of the spores.

The various *reproductive bodies* in fungi, collectively known as *spores*, are either sexual or asexual in origin.

Sexual spores originate in two distinct ways. The simplest method is where two distinct branches of equal size and without any apparent sexual differentiation approach each other, the tips of the two branches become swollen and filled with protoplasm, the walls are absorbed at the point of contact, the two protoplasms mingle, and a new cell or spore is formed. A spore produced in this way is called a *zygospore*.

<sup>7</sup> Mem. Acad. R. Sci. Belg., xxxvii. (1885.)

Zygospores are produced by the primitive algal-like fungi, and are homologous with the zygospores in the simple green algæ. In the second method of sexual spore production the sexual organs are distinctly different in size and function. The male organ or *antheridium* is usually much smaller than the female organ or *oogonium*. In many instances the oogonium is the enlarged terminal cell of a hypha, which increases in size until it becomes spherical, the antheridium growing out as a lateral club-shaped branch from the hypha immediately below the oogonium. When the oogonium and antheridium are replete with protoplasm, the cavity of each is cut off from communication with the cavity of the hypha by the formation of a transverse septum. Next a portion of the protoplasm in the oogonium forms a spherical mass, which is known as the *oosphere*. After this differentiation has taken place, the antheridium comes in contact with the wall of the oogonium, and at the point of contact develops a slender outgrowth called the *fertilization-tube*, which pierces the wall of the oogonium, and increases in length until it comes in contact with the oosphere. Through this fertilization-tube the protoplasm and nucleus contained in the antheridium passes and mingles with the protoplasm of the oosphere. After this blending of protoplasm, which constitutes fertilization, the oosphere is called an *oospore*, which undergoes further changes, clothes itself with a firm cell-wall, and usually after a period of rest, germinates and gives origin to a new individual. Sometimes, as already stated in the case of *Peronospora*, the oogonium is formed from an intercalary cell of a hypha

having the antheridium developed in close proximity, or the latter may be produced by a distinct hypha. In many instances both terminal and intercalary oogonia are present in the same species. This method of sexual reproduction is also met with in the algal-like species of fungi, and as already stated has its homologue in such green algæ as *Vaucheria*. In some species more than one oosphere is formed in the oogonium. The above groups of fungi are collectively known as the *Phycomycetes*.

Passing from the above examples, where the sexual nature of the organs described is universally admitted, we come to a very large section of fungi called the *Ascomycetes*, characterized by having their spores produced in asci, or large, specialized, club-shaped or cylindrical cells, which are usually produced in considerable numbers on a well-developed and frequently highly-differentiated sporophore. As to whether the asci are sexual or asexual in origin is not definitely settled. It is certain that in numerous cases structures homologous to the sexual organs of the *Phycomycetes* are present. For example, in some species two branches, morphologically indistinguishable, coil round each other and come in contact by their tips, thus recalling to mind the sexual mode of fertilization described as conjugation; in others there are two structurally different organs, resembling antheridia and oogonia, whereas in others again certain structures are present closely resembling the organs of reproduction present in the *Floridæ* or red sea-weeds. De Bary accepts the view that in many instances the sexual organs are of functional value, as in the

*Phycomycetes*, and further that the sexual organs originate from special hyphæ called *ascogenous hyphæ*, which are distinct from the hyphæ forming the remaining portion of the sporophore. According to this view the whole of the asci spring from the fertilized portion. Brefeld, on the contrary, considers that sexual organs of functional value are confined to the *Phycomycetes*, and that the similar looking organs in the *Ascomycetes*, even if homologous with those of the *Phycomycetes*, have so far degenerated as to possess no functional value, hence according to Brefeld, the *ascospores* (the name given to spores produced in asci) of the *Ascomycetes* are asexual in origin. In another very large group of fungi, the spores are of undoubted asexual origin. Here the spores are produced externally by large specialized cells called *basidia*. According to Brefeld there are two principal types of basidia, which are adopted by this author as furnishing characters for separating the great group known as *Basidiomycetes* or basidia-bearing fungi, into two primary groups, the *Protobasidiomycetes* and the *Autobasidiomycetes*.

It has been stated that in the *Phycomycetes*, or sexual fungi, secondary asexual reproductive bodies called gonidia are commonly present, and accepting for the moment Brefeld's view that in the *Ascomycetes*, which follow the *Phycomycetes* in ascending order, the apparent sexual organs have lost their functional value, it is not denied that the ascosporous form of fruit in the *Ascomycetes* is the homologue of the sexual product in the *Phycomycetes*, and it is very generally accompanied by a gonidial and truly asexual form of

reproduction. In the *Ustilagineæ* and the *Uredineæ*, illustrated by "rust," "bunt," and "mildew" on corn, the last vestiges of the sexual form of reproduction disappear, the gonidial condition alone remaining, and in the *Basidiomycetes* the gonidiophores or hyphæ directly bearing the gonidia have assumed characteristic and permanent forms, henceforth known as *basidia*, and the reproductive bodies to which they give origin are called *spores*. In the *Protobasidiomycetes* the basidia are septate; in the genus *Pilacre* the basidium is formed from the cylindrical, swollen tip of a hypha which is divided into four equal cells by three transverse septa, each cell giving origin to a single spore. In *Tremella* the basidia appear as the swollen tips of hyphæ, which soon become divided at the apex by two vertical septa crossing each other at right angles, each of the four apical portions elongates into a long, slender, tapering tube, continuous with the cavity of the swollen basal portion or basidium, known as a *sterigma*. Each sterigma finally becomes swollen at the apex, into these swellings the whole of the protoplasm contained in the basidium and sterigmata becomes concentrated, the swollen tips are then separated from the cavity of the sterigmata by the formation of the transverse septa, and drop off as mature spores. In the *Autobasidiomycetes* the basidium is met with in its most highly differentiated condition, and consists at first of a large, terminal, clavate cell, producing at the apex four slender, spine-like sterigmata, each carrying a spore at its apex. In *Dacryomyces* and allied genera only two sterigmata are present on a basidium. In all cases basidia are



the modified tips of ordinary hyphæ. Spores produced on basidia are called *basidiospores*. Basidia are usually produced in considerable numbers, and stand side by side, their tips collectively forming the free surface of the structure, which is known as the *hymenium*. In addition to basidia, other structures are usually present in the hymenium, called *paraphyses* and *cystidia*. The former resemble basidia in shape, but are usually smaller, never produce sterigmata, and are by some authors considered as barren basidia. Cystidia are cylindrical or fusiform cells, usually much larger than the basidia in the same hymenium, and project above the general surface. In some sections of the *Basidiomycetes* they are very numerous, giving to the hymenium a velvety appearance; in others entirely absent. The most important function of cystidia is in connection with *transpiration*, or the escape of water from the tissues. This function can be well studied in the species of *Peniophora* which form broadly-extended whitish or buff-coloured patches on old trunks, to which they are firmly attached by the whole of the under surface, the upper or free surface being entirely covered with the hymenium. Under a pocket-lens the hymenium appears minutely *setulose* or velvety, and if a thin section through the fungus is examined under the microscope, the under surface will be seen to consist of densely interwoven hyphæ, from which originate the elements of the hymenium, basidia, paraphyses, and numerous, relatively very large, fusiform cystidia. These latter are colourless, and have their walls at first perfectly smooth, but with age the portion projecting above the level of

the hymenium becomes crusted externally with minute, colourless masses of oxalate of lime. Now, oxalate of lime is a product of metabolism, and so long as it remains in contact with the cell-sap is held in solution, and in this condition is carried out of the tissues through the cystidia along with the water of transpiration. Once outside the tissues, the water evaporates, leaving the lime in the solid condition. In *Hymenochaete*, a genus allied to *Peniphora*, the very numerous, elongated cystidia have very thick walls, of a dark brown colour, and remain perfectly smooth, and do not appear to be concerned with transpiration. In the *Basidiomycetes* it is perfectly certain that the three organs described as constituting the hymenium are homologous. Those hyphæ of the hymenophore that give origin to the hymenial elements usually become branched in a corymbose manner, and it is not difficult to meet with such corymbs loosely compacted or even isolated in the simpler types, as *Corticium*, *Coniophora*, and *Peniphora*, where the hymenium is frequently imperfectly developed. Such examples not unfrequently have the terminal branches of the corymb differentiated into basidia, paraphyses, and cystidia respectively.

Cystidia have not been met with in the *Ascomycetes*, paraphyses on the other hand are generally very numerous and homologous with the paraphyses of the *Basidiomycetes*, inasmuch as both originate from the hyphæ of the sporophore, but if the idea proves to be correct that the asci originate from ascogenous hyphæ, distinct from the hyphæ of the sporophore,

and the outcome of sexual fertilization, then the asci will not be homologous, but only analogous with basidia.

In addition to the modes of reproduction already described, which are the most highly evolved in the various sections of which they are respectively characteristic, it is important to bear in mind that other modes of reproduction exist, in fact thousands of fungi have two, and in many cases more than two, distinct forms of reproductive organs, usually very dissimilar in both structure and origin. All such as do not come under the types of reproductive organs already described, are known collectively as *gonidial* modes of reproduction, and agree in being asexual in origin. Such gonidial reproductive organs are most frequent in the *Phycomycetes* and *Ascomycetes*, but are by no means rare in the *Basidiomycetes*, and in the first named group are as a rule far more characteristic of the species, from the systematist's point of view, than the sexual reproductive organs. For example, in many species of *Mucor*, popularly called *moulds*, and *Peronospora*, the white cobweb-like *mildews* on the leaves of living plants, the gonidial stage is the only one known. In such cases the accepted proof that the gonidial condition of a species, where the sexual stage is unknown, belongs to the same genus as another species having both gonidial and sexual modes of reproduction, depends on close morphological and biological agreements between the two gonidial forms. In other species the gonidial phase is absent. Gonidial or secondary reproductive organs present far more variety of structure than the primary ones already described, and will be explained

in detail under the various groups to which they belong. At present it will be sufficient to state that the spore-like bodies called *gonidia* may be produced in a mother-cell by free cell-formation. In such cases the mother-cell is called a *sporangium*, and is at least analogous with an ascus, and the contained gonidia analogous with ascospores. In some genera belonging to the *Phycomycetes*, as *Phytophthora*, *Cystopus*, and *Achlya*, the gonidia on their escape from the sporangium possess the power of spontaneous movement for a limited period, and are called *swarm-spores*, *zoospores*, or *zoogonidia*, on account of their animal-like movements. In the *Ascomycetes* the gonidia are almost always produced at the tips of slender hyphal filaments, which either remain short, densely crowded, and contained within a pseudo-cellular covering, or remain naked, that is, not contained within a special covering, and in this case the hyphæ are frequently much branched. To this last type belong most of the forms popularly known as moulds, but it must be borne in mind that the term mould has no scientific value, and also includes many forms of gonidia produced in sporangia, as in *Mucor*. In the *Phycomycetes* and *Ascomycetes* the gonidial stage often precedes the ascosporous condition, but in numerous instances in the same groups the two phases develop simultaneously. Until recently gonidia were considered rare in the large division of the *Basidiomycetes*. Brefeld, however, has shown that in this group gonidial forms are as general and as various in structure as in any other group, and may develop as independent structures or spring from the basidia producing sporophores. The hyphæ

giving origin to gonidia, whether contained in sporangia or naked at the tips of the branches, are called *gonidiophores*. It will doubtless have been already observed that the gonidia produced at the tips of hyphæ are homologous with basidiospores, inasmuch as both are asexual in origin, and in the *Basidiomycetes* both originate from specialized hyphæ forming the same sporophore, and in all probability, in the last named group more especially, the difference between gonidia and basidiospores may be expressed by the statement that the two forms represent the two extremes of differentiation of one primitive type, the gonidial mode of reproduction. The reason for this statement will be better understood later on.

It has been already mentioned that in certain species the gonidial form alone is present, and also that when such gonidial forms approximate closely to others having also the higher reproductive condition developed, the incomplete form is considered as belonging to the same genus as the perfect form, or that possessing both modes of reproduction. As an example of the above; according to the old method of classification, before it was known that certain fungi possessed two or more distinct modes of reproduction, it was considered that every spore or gonidia-producing form was a true and distinct species. Now, according to this idea, several mould-like fungi producing naked spores (gonidia of to-day), and agreeing in all essential points, were included in a genus called *Botrytis*, or *Polyactis* of some authors. This assemblage of forms was accepted as constituting a genus consisting of genuine and complete individuals, until it

was clearly proved that one species, *Botrytis cinerea*, common in Britain, formed a sclerotium, and that this sclerotium, after a period of rest, gives origin to one or more sporophores, producing spores, contained in asci and agreeing in every detail with the genus *Peziza*, belonging to the Ascomycetes. Now this important discovery reduced the supposed species, *Botrytis cinerea*, to that of the gonidial form of the ascomycetous fungus *Peziza Candolleana* (= *Hymenoscypha Candolleana*). Since this discovery, fungologists, from analogy, consider that all the supposed species of the old genus *Botrytis* are gonidial forms of *Peziza*, and consequently the genus *Botrytis* has been abolished. Such genera as *Botrytis*, that have from time to time been established for the reception of forms that have since been shown to be gonidial conditions of other fungi, are called by De Bary *form-genera*, and the species included in such genera *form-species*. According to the old methods of classification, three large groups of fungi, *Hyphomycetes*, *Sphærospideæ*, and *Melanconicæ*, the two latter (= *Coniomycetes* of some authors) including over eight thousand species from all parts of the world, are considered by many to consist entirely of form-genera and form-species, and that they are in reality not entities in themselves, but gonidial forms belonging mostly to the Ascomycetes. Recent researches on the life-history of fungi and special methods of culture have proved this view to be correct in numerous instances, yet there is a large number of these supposed form-species that have not been shown to have any connection with any higher species. This may be to a great extent due to the fact

that no attempt has been made in this direction, and it is probable that in many cases the higher form of a species has been completely arrested, the gonidial phase alone remaining. And again, in many instances where two forms of reproduction have been clearly proved to exist, it has been shown that the two forms need not necessarily alternate, but that either form, more especially the gonidial phase, can reproduce itself for an indefinite period, the sexual or higher form being rarely developed.

Tulasne was the first to indicate clearly the fact that numerous forms hitherto accepted as species were but phases in the development of other fungi, and this condition of things he called *pleomorphism*, which is the term at present used to express the occurrence of more than one independent form in the life cycle of a species, and as already stated, pleomorphic fungi are the rule rather than the exception. Tulasne's discovery has been developed and rendered practicable by the exact method of conducting artificial cultivations introduced by De Bary, to whom more than to any other individual we are indebted for the knowledge we possess relating to the morphology and pleomorphism of the fungi. The fact of two or more forms growing in close proximity or even apparently from each other, or following each other always in the same order of time, does not prove that such forms are stages in the development of one individual; such occurrences may be accepted as suggestive, but it must ever be remembered that the only proof of two or more forms being stages in the life cycle of one species depends on being able to produce the one

form from the spores or gonidia of the other, or to show that the two phases are in organic continuity. Parasitism between fungi has led to mistakes in this connection.

In the *Uredineæ*, a group of fungi parasitic on living plants, pleomorphism was first demonstrated by De Bary, who showed that three independent forms, hitherto considered as distinct species, were in reality only phases in the life cycle of one species. The first form, called *Uredo linearis*, appears on the leaves of wheat during the summer in the form of minute red streaks formed by closely compacted, one-celled, brown, minutely warted spores; during the autumn the same mycelium that produced the *Uredo* during the early part of the year gives origin to blackish streaks consisting of spores that are quite distinct from the *Uredo* spores in being smooth, two-celled and darker in colour. This received the name of *Puccinia graminis*. The *Puccinia* spores, after having remained during the winter in a passive state, germinate and produce small secondary spores, these must find their way on to the surface of a barberry leaf, where they germinate, enter the tissues of the leaf, and within a short period of time give origin to a minute fungus that was called *Æcidium berberidis*, and popularly known as *cluster-cups*. Finally, when the *Æcidium* spores are placed on the leaves of young wheat plants, the *Uredo* form is again produced. Now, in the above example of pleomorphism, it can be proved beyond doubt, and with comparative ease, the three forms enumerated are phases belonging to one species, because the spores of the *Uredo* stage can be



made to produce the Puccinia stage by sowing them on wheat leaves in the autumn, and the Puccinia spores, if kept until the following spring and then placed on a barberry leaf, in turn produce the *Æcidium* stage, the spores of which when placed on wheat leaves, commence the cycle afresh by giving origin to the Uredo stage. The complete fungus, including the three forms, is now known as *Puccinia graminis*. Although the above sequence of forms is what may be termed the normal order of things in the development of the species, yet it has been shown that the existence of the species is not dependent on the rigid following out of this sequence. It is well known that the spores of the Uredo form when sown on wheat, and also some other grasses, give origin to a similar Uredo form during the summer months, and further, that under certain unknown conditions the Uredo and Puccinia forms can reproduce themselves for several years in succession, without the intervention of the *Æcidial* form; hence, although proved beyond doubt that the forms above given belong to one species, yet we are not thoroughly acquainted with the relative importance of the several forms as affecting the existence of the species, in other words, we do not know its complete life-history; and it is not saying too much to state that we are not at present acquainted with all the possibilities involved in the life-history of any one fungus. Nevertheless, much is known in this direction, and new observations are being daily added to the stock of information. Undoubtedly mistakes and misinterpretations are made, as would naturally be expected in connection with such investigations,

but the honest worker can well afford to ignore the ridicule so liberally meted by many members of the Friesian school of fungologists; and at the present day, the person who considers that investigations connected with the life-history of species are not indispensable factors, may safely conclude that he has mistaken his vocation in taking up the study of fungi as a scientific pursuit. Of course, there is no absolute harm in a person endeavouring, by the aid of books and pictures, to find out the name given by some one else to the fungi met with during excursions, nor even in drawing up a list of the same for publication, but at the same time it does not require more than a mind of average constitution to realize that the amount of time and labour bestowed in the production of such a list results in the minimum of additional knowledge imparted to the world at large.

The *host* is the name given to any plant or animal supporting a parasitic fungus. It will have been noted that the pleomorphic fungus, *Puccinia graminis*, lives at different periods on two distinct host plants, the *Uredo* and *Puccinia* stages being passed on wheat or some graminaceous plant, whereas the *Æcidium* stage is spent on barberry leaves. The term *Heterœcism* or *Metaœcism* is used to express this condition of things, and in the *Uredineæ* heterœcismal species are common.

In connection with the study of fungi, the word *spore* can scarcely be said to have a scientific or exact meaning. It has always been used in connection with specialized reproductive bodies, but, as already explained, reproductive cells are of various kinds, and

originate in various ways, some sexual, others asexual. Then again, in the *Basidiomycetes*, where there is supposed to be no trace of sexual organs, we find differences of degree in the spores, as basidiospores and the organs we have called gonidia. Numerous classifications of the various kinds of spores have been suggested from time to time, and every classifier as a matter of course gives a new set of names to the various forms. But all such arrangements are premature, for the simple reason that we do not know the relative functions or origin of the various kinds. As an example, it has been suggested that the term spore should be reserved for reproductive cells of sexual origin. This idea answers very well for what we have called oospores and zygosporcs, where the sexuality is placed beyond doubt and universally admitted, but when we come to ascospores a grave difficulty arises, because, as already stated, the best authorities are diametrically opposed in opinion as to the presence or absence of sexual organs of functional value in the *Ascomycetes*. Equally grave difficulties present themselves in connection with what we have termed gonidial forms.

Using the term spore in the broader sense already indicated, the general structure is as follows:—when ripe the cell-membrane consists of two layers, an outer, the *exospore* or *epispore*, and an inner, the *endospore*; these may in turn be stratified, and, on the application of sulphuric acid, split up into several layers. In *acrogenously* formed spores, that is, spores formed by differentiation of the tip of a hypha, as basidiospores, in addition to the epispore and endo-

spore, there is frequently present a layer external to the epispore, which is in reality a continuation of the wall of the parent hypha, the true spore with its own cell-membrane, composed of epispore and endospore, being differentiated within the hyphal wall. This external membrane De Bary calls the *primary lamella*. In addition to the membranes already described, many spores, both acrogenous and ascospores, have a gelatinous outer layer, which swells up in water and eventually disappears. This gelatinous substance, in the case of many ascospores, forms variously shaped appendages to the spores. Its origin is uncertain. In coloured spores the colour is usually confined to the epispore, which may be smooth or variously ornamented with warts, spines, or ridges, the latter frequently anastomosing to form a reticulation. The endospore is smooth and usually colourless. Some spores have pits in their membrane, which in many species serve as places of exit for the germ-tubes during germination, and are called *germ-pores*; in other instances these pits serve no known function.

Nuclei, as already stated, have been demonstrated in many spores, but the term nucleus as used by systematists refers to drops of oil or some fatty matter, and disappears on the application of dilute hydrate of potash. The *dispersion* of spores is effected in various ways. A common method in many *Ascomycetes* is as follows:—when the spores are mature, the wall of the ascus, which is elastic, becomes considerably extended by a constantly increasing quantity of watery fluid. This expansion is most marked in the upper half of the ascus, and when the wall has reached its maximum

of extension, suddenly becomes ruptured near the apex; at the same time the elastic lateral wall contracts, and the spores are driven out through the opening. In many species there is a definitely circumscribed apical portion of the ascus which is either carried completely away or remains attached by one side after dehiscence, the spores passing through the opening formed. In many *Ascomycetes*, especially in the group known as the *Discomycetes*, the spores are ejected in little clouds at intervals, due to the simultaneous dehiscence of numerous asci. This "puffing" can be produced by shaking the fungus or by an elevation of temperature. If a mature gill-bearing fungus, as the common mushroom, is fixed with the gills downwards about an inch above a sheet of white paper, and allowed to remain for some hours, the spores will fall, and it will be seen that they have spread on the paper for some distance beyond the radius of the pileus, showing that they have been ejected by some means, and that this dispersion is not due to a disturbance of the atmosphere, can be proved by placing a bell-jar over the fungus. According to Fayod,<sup>8</sup> when the spores are mature, water accumulates in the sterigmata, which causes a sudden expansion of the septum at the apex, and the spores are jerked off. In the group including the puffballs, *Lycoperdon*, and the earth-stars, *Geaster*, there is a dense mass of differentiated hyphæ forming the *capillitium*, which assist by their elasticity in dispersing the spores, while in the *Phalloideæ*, illus-

<sup>8</sup> Histoire Naturelle des Agaricinés. Ann. Sci. Nat., ser. vii., vol. ix., p. 181.

trated by the common stinkhorn, *Ithyphallus communis*, there is usually a combination of colour, smell and a sweet mucilaginous substance in which the minute spores are imbedded; these attractions draw numerous flies, that feed on the sweet mucus containing the spores, which are supposed to be dispersed through their agency.

In concluding this portion of the subject, I venture once more to impress on the reader the fact that a clear knowledge of the structure or morphology of fungi is indispensable as a preliminary to their study from the systematic standpoint; and further, that De Bary's work on this subject, which has been translated into English,<sup>9</sup> is the best that can be obtained, and I take the opportunity of acknowledging my indebtedness to this work in preparing the foregoing. Brefeld's works<sup>1</sup> on fungi, written in German, also contain a mine of information, dealing more especially with the life-history of species.

Those desirous of working at the life-history of fungi will do well to study an article by Professor Marshall Ward,<sup>2</sup> as illustrating the exact method followed in tracing the history of a minute mould belonging to the form-genus *Polyactis*, and I may add that we have several more species belonging to the same genus in Britain, along with hundreds of others respecting whose life-history we know nothing.

<sup>9</sup> Comparative Morphology and Biology of the Fungi, Mycetozoa, and Bacteria. English Edition. (Clarendon Press Series.)

<sup>1</sup> Untersuchungen aus dem gesamtgebiete der Mykologie. Heften I.-VII.

<sup>2</sup> A lily disease. Annals of Botany, vol. ii., No. vii., Nov., 1888.

## GEOGRAPHICAL DISTRIBUTION.

According to the latest systematic work on fungi,<sup>3</sup> there are over thirty thousand known species from all parts of the world. This number, of course, includes what have been called form species, and yet in spite of these vast numbers, owing to our imperfect knowledge of the mycologic flora of many large areas, it is impossible to compare the flora of one continent with that of another, excepting Europe and North America, yet sufficient is known to justify the statement that fungi are as widely distributed as any other forms of plant life. One great drawback to the mode of life adopted by fungi, that of being saprophytes or parasites, as compared with chlorophyll-bearing plants, is their dependence on the presence of the latter, because, disregarding the comparatively few fungi that depend on members of the animal kingdom for their food, we find that the great bulk of species obtain their food directly from the vegetable kingdom, and to a very great extent from the phanerogamic division. This dependence is most pronounced in the case of fungus parasites, and more especially in the numerous cases where the fungus has become so specialized as to be confined to the members of one particular natural order of flowering plants for its host, and in many instances even confined to a single species, hence the distribution of parasitic fungi is limited to the distribution of their hosts. But as a rule the distribution of the fungus is more restricted than that of its host; nevertheless, such minute fungi are often very per-

<sup>3</sup> *Sylloge Fungorum.* P. A. Saccardo.

sistent in following their hosts. The potato was introduced into Europe by the Spaniards before the middle of the sixteenth century, and its fungus parasite, *Phytophthora infestans*, found on the wild potato in Chili and Peru, followed, or at all events first attracted attention by its sudden onslaught on potato crops two hundred years later. Saprophytic fungi enjoy a greater amount of freedom in this respect, yet the great majority obtain their food from decaying vegetable matter, and here too, in most instances a certain amount of selection is exercised, as it is well known that we have fungi characteristic of fir-woods, beech-woods, open pastures, &c. The general distribution of the large fleshy and woody species is best known, and the soft, annual, gill-bearing species, included in the genus *Agaricus* in the wider sense, are especially characteristic of the colder parts of the north temperate zone, but species are scattered throughout the tropics, more especially at great elevations. The more persistent and leathery or woody gill-bearing species which connect the *Agaricineæ* with the *Polyporeæ*, as *Lenzites* and *Lentinus*, are cosmopolitan, but are far more numerous and more highly developed in the tropics. In the *Polyporeæ* the genus *Boletus* is characteristic of cold zones, *Polyporus* and *Trametes* extend from the colder portions of the north temperate zone to the tropics, but both genera are by far most numerous in the latter region, while the genera *Favolus*, *Hexagona*, and *Laschia* are very common in the tropics and exceedingly rare in temperate regions. The following summary the of distribution of the *Hymenomycetes*



by Cooke<sup>4</sup> generally holds good. "When the majority of the species of a genus are of a fleshy consistence, it may generally be concluded that that genus belongs to a northern region, even if it should have some representatives in lands which enjoy more sunshine. Thus the *Hydnea* are the principal ornaments of northern forests, where they attain so luxuriant a growth and beauty that every other country must yield the palm to Sweden in respect to them. In an allied genus, that of *Irpea*, the texture assumes a coriaceous consistence, and we find its species to be more especially inhabitants of warm climates." In the *Gastromycetes*, the most highly differentiated genera are characteristic of tropical regions, this is more especially true of the *Phalloideæ*, of which group we have only four European species, and of these three are met with in Britain. The *Lycoperdeæ* are most abundant in cool regions. The species of *Lycoperdon* are widely distributed, one common British species, *Lycoperdon pusillum*, has the following known range: Europe, North America, South America, Tropical and South Africa, Lower Pegu, East Nepal, Java, Ceylon, China, Bonin Islands, Australia, New Zealand. Too little attention has been paid by travellers to the collection of minute fungi to enable any estimate of their distribution being given, nevertheless sufficient is known to show that all the families are represented in every part of the world. It is a fact well known to field mycologists that the relative abundance of species or individuals during a given season depends on a combination of circumstances

<sup>4</sup> "Fungi, their Nature, Influences, and uses," p. 274.

not clearly understood, and it is further known that no one set of circumstances is equally favourable to the development of all species; for example, a survey of the reports of our various fungus forays, extending over several years, which refer almost entirely to the *Agaricineæ*, reveal such statements as the following:— A great scarcity of white-spored species; *Cortinarii* especially abundant; brown-spored species practically absent, &c. The same remarks apply to the minute parasitic species. It has been noted that after a succession of two or three dry seasons there is always a scarcity of fleshy fungi, however favourable the following season may be. This favours the idea that the spores of the *Agaricineæ* do not retain their vitality longer than a single season. As a rule, it may be stated that in temperate regions, dry weather, especially if the temperature is high, checks the development of fungi, whereas moist weather with a sufficiently high temperature, favours their development, but moisture alone does not effect this object.

#### FOSSIL FUNGI.

The tissues of the majority of fungi are ill adapted for preservation in a fossil state, hence the group is but poorly represented. Nevertheless, evidences are not wanting to prove the existence of fungi at geologically early periods. Mr. Worthington G. Smith has described<sup>5</sup> and figured a member of the *Phycomycetes* resembling the recent genus *Peronospora*, found in

<sup>5</sup> Gard. Chron., Oct. 20, 1887; also in "Diseases of Field and Garden Crops," p. 331.

the tissues of a fossil *Lepidodendron* from the coal measures. It is called *Peronosporites antiquarius*. W. Sm. Mycelium is met with in the tissues of the vascular cryptogams in early *Palæozoic* times. The *Ascomycetes* are first met with under forms closely resembling *Sphæria* in the Cretaceous rocks, while the *Basidiomycetes* first appear under the form of *Polyporus* and allied woody genera in tertiary times. The sequence indicated above, from the *Phycomycetes* or algal-like fungi to the *Basidiomycetes*, agrees with the idea already expressed regarding the evolution of the fungi. The lichens as a group were probably differentiated at a much later geological period than the fungi, and are first met with in a fossil state in tertiary rocks, where such genera as *Parmelia*, *Ramalina*, *Lecidea*, *Cladonia*, and *Graphis* occur, and have continued to the present time.

#### LICHEN-FORMING FUNGI.

Up to the year 1860 the time-honoured group of *Thallogens* or *Cellular plants* was considered to consist of three well-defined sections, *Algae*, *Fungi*, and *Lichenes*, collectively characterized by the absence of fibro-vascular elements. At the present day it has been shown that only two divisions exist, and further that the supposed absence of highly differentiated tissues is not supported, but disproved, by recent researches. The following remarks by Dr. Scott<sup>6</sup> explain sufficiently the latter statement:—"Very

On some recent progress in our knowledge of the Anatomy of Plants, *Ann. Bot.*, vol. iv., p. 147.

striking advance has recently been made in our knowledge of the internal structure of other classes of plants, and especially of the *Algæ*. . . I need only call attention to the discovery of sieve-tubes in the larger brown *Algæ*. The work of Parker, Will, and Oliver has shown that these structures are in all respects comparable to the sieve-tubes of the highest plants—a surprising result, which by itself is sufficient to show that the term ‘cellular-plants’ can no longer be applied generally to the *Algæ*. There can be no doubt that further investigation will bring to light a very high differentiation of tissues in some of these plants.”

Concerning the primary divisions of the *Thallophytes*, the *Algæ* and the *Fungi* are yet considered as possessing their individuality. The *Lichenes*, however, have been proved beyond doubt to consist of fungi parasitic upon *algæ*. It has been already stated that numerous fungi are parasitic on *phanerogams* or flowering plants, but in most such cases the fungus is parasitic in the generally accepted sense of the term parasitic, the benefit being all in favour of the fungus and to the decided disadvantage of the host, whereas in lichens—fungi parasitic on *algæ*—both parasite and host mutually benefit, and frequently to such an extent that neither parasite nor host can exist independent, but to this statement there are proved exceptions. This condition of things is expressed by the various terms, *commensalism*, *mutualism*, *symbiosis*, &c. The algal portion of the fungus, possessing chlorophyll, assimilates carbonic dioxide, and forms organic carbon compounds, while the mycelium of the

fungal portion absorbs the required mineral substances from the substratum. Schwendener was the first to indicate the true nature of lichens.<sup>7</sup> Bornet followed<sup>8</sup> by showing that in numerous instances the so-called gonidia or algal portion of lichens could with certainty be referred to known species of algæ, and further succeeded in producing a lichen synthetically by sowing the spores of *Parmelia parietina* with *Proto-coccus*. Quite recently Bonnier has published<sup>9</sup> the results of investigations extending over several years on the nature of lichens, and gives a long list of species that he has produced artificially, by sowing the spores of lichens with species of algæ corresponding to those met with in the same species of lichens growing naturally. Various methods of culture were adopted, the details of which are given in detail, and the article teems with additional proofs and corroborations of the correctness of Schwendener's views concerning the nature of lichens. The same author has also shown<sup>1</sup> that the spores of lichens germinate readily on the protonema of mosses, but in this case mutualism is not manifested, consequently we have no perfect lichens having for their chlorophyllose element the protonema of mosses. It is difficult to conceive that lichens originated as we now understand them, and from analogy, it is probable that in the first in-

<sup>7</sup> Untersuchungen über den Flechtenthallus, in Nägeli's Brete. zur Wissensch. Bot., 1860.

<sup>8</sup> Recherches sur les Gonidies des Lichens, Ann. Sci. Nat. (Bot.), vol. xvii., 1873.

<sup>9</sup> Recherches sur la synthèse des Lichens, Ann. Sci. Nat., ser. vii., vol. ix. pp. 1-34, 1889.

<sup>1</sup> Germination des spores de lichens sur les protonémas des mousses, Rev. générale de Bot., vol. i., p. 165, t. 1, 1889.

stance fungi were parasitic on algæ at the expense and ultimate destruction of the latter, and that the present perfect mutualism between alga and fungus has been acquired by degrees. Differences of degree are observable in the parasitism of fungi on phanerogams at the present day, although no known examples of true mutualism between fungi and phanerogams are known to exist. Numerous species of lichens are parasitic on the evergreen coriaceous leaves of phanerogams. In the genera *Coniocybe*, *Sphinctrina*, *Calicium*, &c., universally acknowledged by lichenologists as lichens, several species have no trace of gonidia or algæ, and in the terminology of lichenologists, the thallus or portion containing algæ is then said to be obsolete, but it is not difficult to realize that certain species belonging to a given genus of fungi have acquired the condition of mutualism with an alga while others have not done so. The fungal constituent of the great majority of lichens belongs to the *Ascomycetes*, but recently two small groups of lichens have been discovered where the fungus element belongs to the *Basidiomycetes* and *Gastramycetes* respectively. It is only fair to state that even at the present day most of the leading lichenologists are entirely opposed to the views stated above regarding the nature of lichens, and consider that the whole lichen, including what has been termed alga and fungus respectively, can be produced from the spore of a lichen, but it is important to bear in mind the fact that no one has demonstrated this supposition, and although much has been written by lichenologists supporting the autonomy of lichens, not a particle

of evidence has been brought forward against Schwender's views.

#### MYXOGASTRES.

The *Myxogastres*, *Myxomycetes*, or *Mycetozoa* are names given by different authors to a small but widely distributed group of organisms common in Britain, on decaying wood, &c., under the form of individually small, often brightly coloured bodies, rendered conspicuous by being usually gregarious in habit, and on account of their resemblance in miniature to the puff-balls or *Gastromycetes*, were considered by the old authors as belonging to the fungi. It is now known that the *Myxogastres* are not fungi, from which group they differ in many important features, more especially in the remarkable structure of the vegetative phase, which may briefly be described as follows. The spores on germination give origin to one or more motile zoospores furnished with cilia, or to naked amœboid cells, which after a short period of activity lose their cilia and combine together in considerable numbers, forming a mass of naked protoplasm called a *plasmodium*, frequently of considerable size, and still possessing the power of voluntary movement. The plasmodium is surrounded by a yielding external pellicle, which usually gives a cellulose reaction, but is not broken up into distinct cells enclosed in cell-walls, and there is a total absence of hyphæ. The plasmodium remains during its vegetative phase in the interior of decayed wood, or amongst vegetable humus, where it creeps about in search of food, and

eventually comes to the surface previous to the reproductive phase, when a portion of the substance of the plasmodium becomes differentiated into a protective body or *sporangium*. The remainder of the protoplasm enclosed within the sporangium produces the spores, which are frequently mixed with threads forming the *capillitium*, or spore-dispersing apparatus.

The spores on germination produce a plasmodium. The late Professor de Bary, to whom we are indebted for the greater part of the knowledge we possess respecting the morphology and biology of the *Myxogastres*, considered the group as being more allied to the animal than to the vegetable kingdom, and as having most affinity with the simple animal organisms known as the *Flagellatæ*. The supposed proof of affinity is derived from the peculiar nature of the *Myxogastres* during the vegetative phase as described above, and not from the motile zoospores produced by the spores on germination, as the last character is possessed by many undoubted members of the vegetable kingdom. As to whether the *Myxogastres* are plants or animals cannot be discussed except at considerable length, and does not especially concern us here, where it is sufficient to remember that they differ from the fungi in the total absence of hyphæ and in the formation of a plasmodium.

#### BACTERIA, OR SCHIZOMYCETES.

The *Bacteria* were considered as fungi until recently, mainly on the fact of being cryptogams without chlorophyll. The individual cells are usually exceedingly minute, and when placed under favourable



conditions reproduce themselves by repeated bipartition, each cell dividing into two daughter-cells, through several generations. This bipartition usually takes place in one direction only, and as the cells usually remain in contact for some time, strings of cells result. Some species contain chlorophyll. As a rule the individuals are produced in immense numbers, which are collected in gelatinous colonies, and not unfrequently these colonies are brilliantly coloured. Many forms exhibit movements similar to swarm-spores in fluids; these movements have in some instances been traced to the presence of extremely fine cilia. In addition to the vegetative mode of reproduction by fission, spores are produced, and according to their mode of formation, the group is divided into *Endosporous Bacteria* and *Arthrosporous Bacteria*. In the first group usually one spore is formed within each cell, in the latter group the individual cells become spores. De Bary considers that the course of development of the *Bacteria* does not point to any close affinity with the fungi, and the forms of *Bacillus* and *Spirillum* that contain chlorophyll are certainly not fungi. The same author considers that the starting point of the group is in touch with the *Flagellateæ*, with a divergence towards the *Algæ* and the *Myxogastres*.

#### COLLECTION AND PRESERVATION OF FUNGI.

Fungi can be examined best when fresh, nevertheless, a well preserved specimen is of great value from the systematic standpoint, and in numerous instances suffers so little from drying that, on being

soaked in water, it is almost equal to a fresh specimen.. It is true that in drying the colour in most instances disappears or becomes much duller than when living, but the earnest student will make sketches and notes of those peculiarities presented by the fresh specimens which are certain to disappear on drying, amongst which may be mentioned, colour, smell, taste, viscosity, &c. Habitat should also be noted, and in the case of fungi parasitic on living plants or animals, the name of the host should be given, as in many instances certain species are, so far as is known, confined to one host. But in this connection it is important to guard the student against the slipshod method, in vogue at the present day, of assuming that a fungus is a given species merely because found on a certain host. It may be argued that because the above points are not usually noted in *exsiccati*, or collections of fungi offered for sale, that they are not indispensable, but unfortunately it is too evident that in many instances such sets are prepared for the sole purpose of obtaining a good percentage on the time and money expended on their production.

The numerous *epiphyllous* fungi, or species growing upon leaves, are easily preserved, the leaves being dried between sheets of absorbent paper in the usual way, only sufficient pressure being applied to keep the leaves flat. The minute forms belonging to the *Ascomycetes*, that to the naked eye appear as black or red points on bark and wood, must be cut away with sufficient of the matrix to show the general habit of the species. The pieces must be thoroughly dried before being put away, otherwise they will probably be

covered with mould, and the specimens for which the piece was collected be ruined. In the case of large woody species of *Polyporus* and allied genera, where the entire fungus is too large for herbarium purposes, a section about half an inch thick through the entire fungus gives a good idea of its form and general structure (such sections are easily made with a fine saw). If the specimen has a stem, the section would of course be through the central portion of that part. The surface of the stem should also be preserved, as it often presents characters of importance in the discrimination of species. The numerous form-species collectively constituting the *Hyphomycetes*, and popularly known as moulds, are difficult to preserve, and after being thoroughly dried, are best kept in shallow boxes. In collecting such forms, a portion of the *matrix* or substance on which the fungus is growing is cut away, and when perfectly dry, stuck by means of gum to the bottom of the box, or better still, to the inside of the lid, which can then be removed for examination under a low power of the microscope, the box itself being stuck to a sheet of paper of the size adopted for the herbarium. Sketches showing the general habit, mode of branching, presence or absence of septa, and mode of attachment, also shape of spores, should be made from the fresh specimen; these, if not coloured, should be accompanied by notes describing colour, &c. Moulds, when collected, should be placed separately in small boxes, and pinned down or fixed in some way to prevent the spores from being knocked off, which would certainly happen if placed loose in the box.

The fleshy fungi, containing a large amount of

water, undergo the greatest amount of change in drying. The cup-shaped species belonging to *Peziza* and allied genera, should be allowed to part with their moisture, and then slightly flattened, but not pressed so as to crush the specimens unnecessarily. The larger forms, such as species of *Morchella*, may with advantage be cut down the centre, being too bulky for herbarium specimens when dried entire. The bright colour of the hymenium of many species disappears or becomes changed during drying, and should be noted when fresh, the note accompanying the dried specimen, in fact, a duplicate of the notes and sketches made should always be placed along with the specimen in the herbarium. In the *Agaricineæ*, or gill-bearing fungi, dried specimens, unless carefully prepared, are worthless, hence careful sketches and notes taken from the living specimen are indispensable. The smaller species, after being allowed to part with a considerable amount of moisture, may be placed under slight pressure, and it is best to place the specimens at once on the paper where they are intended to remain, as in pressing they usually stick to the paper. If oiled paper, or the preparation known as vegetable parchment, is placed upon the specimens when first exposed to slight pressure, it can be removed without adhering to the specimens, which after being pressed flat should again be exposed to the air to dry. If sections are not prepared, it is necessary that specimens should be so arranged as to show both upper and under side of the *pileus* or cap, in fact, as the student will readily understand, it is impossible to have too many illustrations of a species, and not simply to illustrate the points

that are considered of specific value at any given period. Special care should be taken to preserve the ring present on the stem of many species, which is often very loosely attached at maturity, and also the *volva* or sheath at the base of the stem, which is also of great importance in determining the section to which the specimen belongs. Hence, in collecting, it is not sufficient to simply pull up the fungus, as by so doing the *volva* would almost certainly remain in the ground, as in many agarics and *Phalloideæ*. Specimens of different ages are required to illustrate properly an agaric, as it is of importance to know whether the margin of the pileus is incurved or straight during the young stage. The mode of attachment of the *lamellæ* or gills to the stem is of great importance, and should always be clearly shown in dried specimens. Finally, the spores should be preserved in the mass in a separate packet, and placed with the specimen in the herbarium. These may be obtained by cutting off the stem of a mature specimen, and placing the pileus, gills downwards, on a piece of paper, and allowing it to remain until the spores fall on the paper. If the specimen is a dark-spored species, generally indicated by the colour of the gills, white paper should be used, and black paper when the spores are white. The large fleshy agarics and *Boleti* should be cut into sections and allowed to dry for a day or two before pressure is applied. Changes of colour in the flesh when broken should be noted, also the presence of "milk" or *latex*, its colour and taste, whether sweet or acrid. The *Gastromycetes*, including puffballs, &c., are undoubtedly of most value when not subjected

to pressure, but such specimens certainly take up a great amount of room, and if pressed, should be so arranged that the mouth or opening through which the spores escape, can be examined. Sections are necessary, and specimens of various ages are indispensable, as the warts or spines which are present on many species in the young stage eventually disappear, leaving the surface smooth and shining.

There is a difference of opinion as to the best method of preserving specimens in the herbarium. Some people prefer having the specimens loose in envelopes. The advantage of this system is that the specimens can be removed and examined on both sides, the disadvantages are that the specimens are undoubtedly sooner attacked by mites, beetles, and mould when in packets, and there is the danger of mixing specimens when the contents of two or more packets are taken out at the same time for comparison. These dangers are avoided when the specimens are fixed with fish-glue to paper, and when sufficient examples can be obtained to illustrate every condition, the last method is perhaps best, but where a single specimen only exists, of course it should never be glued down, as by so doing half its value is sacrificed. Moulds and other delicate fungi that will not bear friction, should be preserved in shallow boxes. Whichever method is adopted, the packets or papers with specimens glued down should be gummed to larger sheets of the size adopted for the herbarium. Foolscap size is very convenient. One species only should be fixed to a sheet, because as the work of collecting goes on, the same species from other

localities, or different stages of development, will probably be obtained, and it is convenient to have all the specimens of one species together, and in some variable species, two or more sheets of specimens may be necessary to illustrate the sequence of forms. All the species sheets of a genus should be enclosed in a genus cover or folded sheet, with the generic name written outside. The arrangement of specimens in the herbarium must be such as to enable any given species to be found without loss of time, and this is best accomplished by adopting the alphabetical arrangement. The genera of each family should be placed in alphabetical order, and the species of each genus similarly arranged. The herbarium must be kept in a dry place, otherwise the specimens will soon be covered with mould, as many species, even after being thoroughly dried in the first instance, become soft and absorb moisture in damp weather. To guard against the attacks of minute beetles the specimens are sometimes treated with a solution of corrosive sublimate in methylated spirit, but this is an objectionable method, as the sublimate is left in the form of a whitish bloom on the surface of the specimen after the spirit has evaporated, and furthermore, does not destroy the beetles in woody specimens of the *Polyporeæ*, &c. A better remedy is to expose the packets to the fumes of carbon disulphide for two or three days in a closed box, but in a small collection that is constantly under supervision, a little camphor placed in the box or cabinet with the specimens is generally sufficient. The value of a collection in the eyes of some people depends on the number of specimens it

contains, but it may be stated that dried fungi, unless accompanied by notes made from the fresh specimen, including habitat and locality, may be considered in most instances as perfectly useless, consequently never waste time in collecting and drying more specimens, especially of the fleshy fungi, than you can carefully examine in the fresh state. No collection of fungi can be considered complete unless accompanied by specimens preserved in alcohol or methyated spirit. Of course there is a limit to specimens in spirit, on account of the space taken up by bottles, yet typical species of the various types in different stages of development will be found exceedingly instructive.

#### EXAMINATION OF FUNGI.

The most important naked eye and pocket-lens characters to be noted in the fresh specimen have already been enumerated, but no fungus can be considered to have been thoroughly examined, even from the specific standpoint, until its microscopic structure has been investigated. At the present day the specific characters of all the minute forms depend almost entirely on microscopic evidence, but even amongst the agarics, species that are so closely allied as to be frequently confounded from the superficial Friesian means of determination, are often clearly separated by microscopic characters, such characters being usually furnished by those portions of the sporophore forming the hymenium. In agarics the relative size and form of the spores, absence or presence of cystidia, which also vary much in size and form, and are constant in



the same species, are important characters that have been almost entirely neglected. The same remarks apply to the other groups of large fungi.

In reply to this statement, it may be asked, Are microscopic characters of more value than the more superficial ones adopted by Fries? The value of a character depends entirely on its constancy, and evidence is not wanting to prove that such organs as asci, basidia, cystidia, paraphyses, and more especially spores and gonidia are more constant than other portions of the hymenophore, perithecia, or gonidiophores respectively. A little practice will enable any one to cut sections through the gills of an agaric that will show all the organs in their natural position, and when stained with a very weak solution of eosin in water to which a drop or two of acetic acid is added, the preparation may be permanently mounted in glycerine jelly. In the *Ascomycetes*, where spore characters are of great importance in the discrimination of species, it will be found of great advantage to have microscopic preparations as standards of comparison when examining new material. There is a tendency in some quarters at the present day to look upon spores as the only feature of importance in forming genera and species. As to whether an additional septum in a spore is really of generic value depends entirely on the view as to what the term genus really means, a problem at present unsolved, and likely to remain so until we know very much more of the life-history of at least the leading forms belonging to each of the large groups, and in the present unsettled state of the subject it is important in noting the

peculiarities presented by each species on examination, to sketch and describe all its features, and not only those brought into prominence in the text-book used. An imperfect examination is always eventually regretted, and really amounts to so much time wasted, as sooner or later it has to be done over again. Specimens that have been dried require to be soaked in water until fully expanded before their structure can be seen, then, in the case of minute species, they should be carefully examined under a one-inch objective, and afterwards a section should be cut for examination under a higher power. A good quarter-inch objective is generally sufficient to define clearly the minute characters presented by spores, as the number and arrangement of septa or markings on the surface of the wall. Many thin-walled spores, gonidia, and hyphæ collapse when dry, and frequently remain in this condition after the fungus as a whole has expanded in water. In such cases, in fact under all circumstances, it is advisable to place the spores or sections intended for microscopic examination in a weak solution of ammoniac hydrate (liquid ammonia) instead of water on the slide, when in most cases the various portions will become fully expanded in a very short time. But if this does not take place, place a spring-clip over the cover-glass and raise the liquid to boiling point over a spirit lamp. Specimens expanded in this way do not collapse when mounted in glycerine jelly, whereas spores that have been expanded in water only frequently do so. In the microscopic examination of moulds it is important to observe the method of attachment of the gonidia, and also to notice whether

the latter grow singly or *concatenate*, that is, in necklace-like rows. This cannot be done in water, as the gonidia usually break away from each other and from the gonidiophore the instant they come in contact with water, but if placed in alcohol or good methylated spirit no such separation of the gonidia takes place. In examining microscopic fungi do not scrape off the specimen, but cut a section. The latter process is a trifle more difficult to accomplish, but results in something definite. For example, in examining one of the numerous species of fungi parasitic on living leaves, if the spores are scraped off they can certainly be seen, but no idea of the structure of the fungus can be gained, whereas if a section is cut through the entire leaf at the point where the fungus is situated, the attachment of the spores is seen and also the mycelium in the tissues of the leaf. Such sections are not difficult to obtain. If a small portion of the leaf containing a *pustule*, or cluster of spores, of the fungus is cut out and placed on a piece of wood, then a glass slip or other body with a straight-edge placed on the top of the piece of leaf to serve as a guide for the razor or lancet, and a section as thin as possible cut, a little experience will show that two or three sections can be cut without moving the glass slip, and the pressure applied will not injure the specimen.

The razor should be dipped in water before cutting the sections. Species growing on wood or bark are generally sufficiently firm to admit of sections being cut without any pressure from above. Satisfactory sections should be permanently mounted for future reference, not omitting to indicate by a

number or otherwise the specimen from which the section was taken. In like manner references to notes and microscopic preparations should be attached to herbarium specimens.

#### CLASSIFICATION.

The systematic arrangement of species according to their natural affinities is, or should be, the outcome of a knowledge of their morphology, and more especially of the earliest phases of development, or in other words, life-history. The classification of fungi is at the present time in a transition state, due to the fact that the most distinguished workers in the field have devoted the whole of their energies either to the development of a system of classification based entirely on characters presented by mature specimens, and at the same time accepting as a species every independent form. The names of Fries, Berkeley, Cooke, and Saccardo, are closely associated with this school. It has been shown that true affinity can only be determined by an examination of species in the earliest stages of development, and that superficial resemblances presented by mature forms do not necessarily imply relationship in the sense of descent from a common parent form, hence we find such combinations as the *Myxogastres* with the *Gastromycetes*. Nevertheless, in spite of its grave defects, the old system has taught us to observe minute details of structure, and further, has also demonstrated that such minute differences are constant, and consequently must be admitted as being the outward and visible responsions of physiological laws, even if the manifestation is

only expressed by the manner in which the pileus of an agaric is arranged in the young state, the colour of the hymenium of a *Peziza*, or the change in colour of latex when exposed to the air, and such characters, as far as they go, appear to be quite as constant, and therefore as useful in the discrimination of separate forms as any of the characters used by the modern school of biologists. Of course the above characters do not indicate in the least degree the difference between true species as generally understood and form-species, and this indeed is the weak point in the system adopted by the followers of Fries. The labours of the modern school, initiated by Tulasne, De Bary, and Brefeld, have to a great extent remedied this defect of their predecessors, and by pure cultures have clearly demonstrated in numerous instances that the "species" founded by Fries and his followers are but independent phases in the life-history of other forms. So far the biologists have done good, inasmuch as they have indicated the apparently only sure method of determining what is a species, and consequently correcting the mistakes of the earlier school, or rather in adding enormously to the stock of knowledge already possessed by the Friesian disciples, for surely the last mentioned body must have added something to our knowledge of the nature of fungi, although their earnest endeavours are too often treated with scorn by the present generation, and perhaps nowhere do we see such gross abuses of brilliant discoveries as are perpetrated by some of the followers of De Bary. Take the example of heterocism in the case of *Puccinia graminis*, which was demonstrated by De Bary to the satisfaction of everyone not saturated with preju-

dice, but this proof was the outcome of prolonged and laborious investigations, considered by De Bary as being absolutely necessary to prove his point. This discovery naturally suggested the idea that numerous other corresponding forms included in the same group might be in like manner connected, and in many instances careful experiments have proved this to be the case, but at the same time we find in modern works on the *Uredineæ* forms associated together on the merest shadow of proof, such as would certainly not have been accepted by De Bary as conclusive. Similar examples of rushing to conclusions from analogy only are met with in every group ; in fact this slipshod method of relying on analogy, when once a precedent has been clearly established, seems to be the weak point with the disciples of the modern school. The divisions called *Melanconiceæ*, *Sphæropsideæ*, and *Hyphomycetes* include over eight thousand species from all parts of the world. Out of this number less than one hundred have been clearly proved by cultures to be forms of species belonging mostly to the *Ascomycetes*, yet on the strength of this small percentage of proved cases, the three groups are entirely omitted in the schemes of classification given by De Bary and Brefeld, implying that all are considered merely as form-species, a supposition which may be quite correct, but far from being proved, and not altogether countenanced by the investigations of these same authors, who claim to have shown that in some of the *Ascomycetes* the gonidial stage is completely lost. De Bary and his followers do not as a rule accept the "special creation" theory, but judging from their writings, consider that species are

evolved by certain processes of differentiation from previously existing species. If so, assuming that the gonidial stage of an originally pleomorphic fungus alone remains, the ascigerous condition having been entirely arrested, should the gonidial form still be considered a phase of a higher form that has no existence, or, being capable of carrying on an entirely independent existence, will it ever be entitled to rank as a species? If not, then, from the evolution standpoint, all living organisms, from analogy, are merely forms of a primitive progenitor. From the above it will be seen that in a systematic work the *Sphæropsidæ*, *Melanconieæ*, and *Hyphomycetes* must be admitted, and until their affinities are demonstrated by direct experiment, not analogy, it will be well to use the terms genera and species in the ordinary sense.

The following schemes of classification will indicate the views of affinity as understood by the best authorities at the present day.

According to Sachs<sup>2</sup> the fungi are supposed to be side branches from algæ, expressed as follows:—

“Professor Fischer still treats Algæ and Fungi as two entirely distinct series developed in parallel rows; while I suppose that in each class Fungi have diverged as ramifications from various types of Algæ.

#### THALLOPHYTES.

##### Class I. PROTOPHYTA.

|                         |                        |
|-------------------------|------------------------|
| Containing chlorophyll. | Not containing chloro- |
| Cyanophyceæ.            | phyll.                 |
| Palmellaceæ (in part).  | Schizomycetes.         |
|                         | Saccharomycetes.       |

<sup>2</sup> Text-Book of Botany, second English ed., p. 244.

Class II. ZYGOSPOREÆ.

*Conjugating cells mobile.*

|                                |              |
|--------------------------------|--------------|
| Pandorineæ.<br>(Hydrodictyeæ.) | Myxomycetes. |
|--------------------------------|--------------|

*Conjugating cells stationary.*

|                                       |              |
|---------------------------------------|--------------|
| Conjugateæ (including<br>Diatomaceæ). | Zygomycetes. |
|---------------------------------------|--------------|

Class III. OOSPOREÆ.

|                                                                                   |                                  |
|-----------------------------------------------------------------------------------|----------------------------------|
| Sphæroplea.<br>Vaucheria (Cœloblastæ).<br>Volvocineæ.<br>Cedogonieæ.<br>Fucoideæ. | { Saprolegnieæ.<br>Peronosporææ. |
|-----------------------------------------------------------------------------------|----------------------------------|

Class IV. CARPOSPOREÆ.

|                                       |                                                                                          |
|---------------------------------------|------------------------------------------------------------------------------------------|
| Coleochæte.<br>Florideæ.<br>Characeæ. | Ascomycetes { including<br>{ Lichens.<br>Æcidiumycetes<br>(Uredineæ).<br>Basidiomycetes. |
|---------------------------------------|------------------------------------------------------------------------------------------|

Class I. *No sexual reproduction.*

|                |                |
|----------------|----------------|
| Saccharomyces. | Phycobromaceæ. |
|----------------|----------------|

Class II. *Reproduction by conjugation.*

|              |                         |
|--------------|-------------------------|
| Zygomycetes. | Diatomaceæ, Conjugateæ. |
|--------------|-------------------------|

Class III. *Reproduction by oospores.*

*The result of fertilization.*

|                                |                                                                                |
|--------------------------------|--------------------------------------------------------------------------------|
| Peronosporææ.<br>Saprolegnieæ. | Palmellaceæ, Siphonaceæ.<br>Confervaceæ, Fucaceæ.<br>Coleocheteæ, Characeæ(?). |
|--------------------------------|--------------------------------------------------------------------------------|



Class IV. *A compound fructification, resulting from fertilization (alternation of generations).*

Ascomycetes.

Basidiomycetes.

| Florideæ."

Professor De Bary says,<sup>3</sup> "According to the leading points of view indicated, and the present state of our knowledge, a review of the course of development of the several groups of the Fungi arranges them in the following manner.

#### I. SERIES OF THE ASCOMYCETES.

1. *Peronosporæ* (with *Ancylistæ* and *Monoblepharis*).
2. *Saprolegniæ*.
3. *Mucorini* or *Zygomycetes*.
4. *Entomophthoræ*.
5. *Ascomycetes*.
6. *Uredinæ*.

#### II. GROUPS WHICH DIVERGE FROM THE SERIES OF THE ASCOMYCETES OR ARE OF DOUBTFUL POSITION.

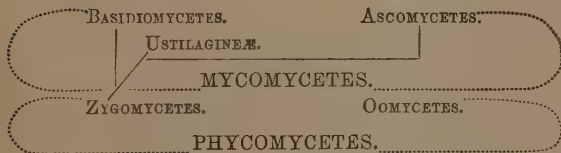
7. *Chytridiæ*.
8. *Protomyces* and *Ustilagineæ*.
9. *Doubtful Ascomycetes* (*Saccharomyces*, &c.).
10. *Basidiomycetes*.

Groups 1—4 have been brought together under the name of *Phycomycetes* on account of their close approximation to the Algæ.

Groups 7 and 8 in the second category will be considered in connection with the *Phycomycetes*; group 9 naturally in connection with 5, and 10 with 6."

<sup>3</sup> Fungi, Mycetoza, and Bacteria, English ed., p. 132.

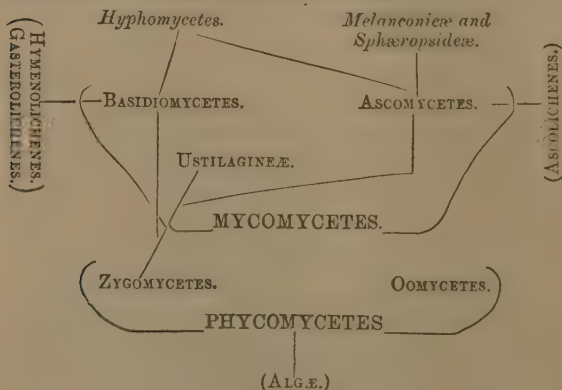
According to Brefeld fungi are divided into two groups, the *Phycomycetes*, or algal-like fungi, characterized by the presence of sexual as well as asexual modes of reproduction, and the *Mycomycetes*, characterized by the absence of sexually produced reproductive bodies, and consequently propagated entirely by asexual conidia (=gonidia of the present work). The *Phycomycetes* are divided into two groups, distinguished by the nature of the sexually produced reproductive bodies, namely *Zygomycetes* and *Oomycetes*. The *Mycomycetes* are also broken up into two primary groups, *Ascomycetes*, having the spores produced in asci, and the *Basidiomycetes*, where the gonidia are borne on basidia. The *Ustilaginæ*, or smut-fungi, are considered to form a transition from the *Phycomycetes* to the *Mycomycetes*, hence according to Brefeld the phyllogeny of the primary groups may be represented as follows:—



The above arrangement shows that all the *Mycomycetes* are in touch with the *Zygomycetes* division of the *Phycomycetes*, whereas the *Oomycetes* are to be considered as a terminal group, in other words, as not being directly concerned with the origin or related to any group of fungi higher in the series. The following scheme of arrangement, copied from Brefeld's

great work,<sup>4</sup> completely upsets all previous arrangements, which familiarity rather than conviction has endeared us to ; nevertheless, every attempt, from that of Persoon up to the present day, has done something towards the present state of things, and it cannot be considered that finality has been attained in the present arrangement, yet remembering that the basis of the scheme rests on the only known sure foundation—life-history of forms—mostly worked out by the author himself, and in such numbers as to give a good opportunity of distinguishing between important and unimportant characters, is sufficient to commend the result to all unprejudiced minds (pp. 72, 73).

In a systematic work the *Hyphomycetes*, *Melanconicæ*, and *Sphærospideæ* must find a place, consequently the following modification of Brefeld's classification will be adopted in the present work.



<sup>4</sup> Op. cit., Heften VII.—VIII.

## PHYCOMYCETES.

The amount of work yet to be done in the present group, even to place it on a level with any other group of fungi, can only be realized by studying the systematic work by Saccardo,<sup>5</sup> where all the described forms are brought together. It is safe to say that the greater proportion of so-called genera and species are only temporary, owing to the fact that our amount of knowledge is so scanty, embracing in but comparatively few instances a complete life-history, hence in almost every genus comprising half-a-dozen species or even less, it is usual to find some species founded on a knowledge of the gonidial phase alone while others are characterized by peculiarities presented by the sexual organs, the gonidial condition being unknown. As a rule, throughout the group the gonidial is far more constant than the sexual mode of reproduction, and carefully conducted investigations tend to show that in some instances either one or the other has been entirely suppressed, most frequently the latter, as in *Phytophthora infestans*. It is also proved that in many other cases where both antheridia and oogonia are present, fertilization does not take place, that is, no protoplasm passes from the germ-tubes of the antheridia into the oospheres. In other instances the antheridia are not developed, consequently the oospores produced by the oogonia are asexual in origin; both these conditions are met with in the *Saprolegnieæ*. A typical zygosporangium originates as follows: the two lateral

<sup>5</sup> Syll. Fung., vol. vii. Part I.

## NATURAL SYSTEM OF

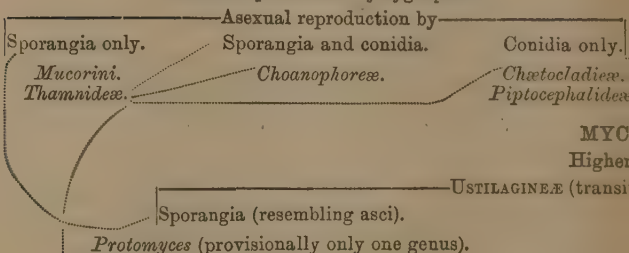
PHYC

Lower algae

## Class I.

## ZYGOMYCETES.

Sexual reproduction by zygospores.

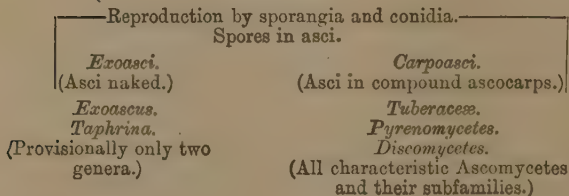


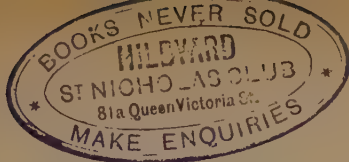
MYC

Higher

## Class I.

## ASCOMYCETES.





## LÆ-FORMING FUNGI.

TES.

al fungi.

## Class II.

## OOMYCETES.

Sexual reproduction by oospores.

Asexual reproduction by—

Sporangia or conidia.

Conidia only.

*Peronosporæ.**Entomophthoræ.**Saprolegniæ.**Chytridiaceæ.*

ES.

ungi.

). Reproduction by—

Conidia (resembling basidia).

*Ustilago, Tilletia, Sorosporium, &c.* (including the remaining forms of the Ustilagineæ).

## Class II.

## BASIDIOMYCETES.

Reproduction by conidia only. Conidia borne on basidia.

*Protobasidiomycetes.*  
(Basidia divided.)Angiocarpous.  
*Pilacreæ.**Autobasidiomycetes.*  
(Basidia not divided.)

Angiocarpous.

Gynocarpous.

*Lycoperdaceæ.**Dacryomycetæ.**Nidulariaceæ.**Clavariæ.**Phalloidæ.**Tomentelleæ.**Hymenogastresæ.*

Hemiangiocarpous.

*Thelephoræ.**Hydnæ.**Polyporeæ.**Agaricineæ.*

branches, alike in size and structure, called *archicarps*, which are at first short and resemble ordinary hyphal branches, approach each other until their tips touch. The archicarps continue to increase in size for some time, and become *clavate*, or club-shaped, and densely filled with protoplasm. At this stage a portion of the thick tip of each archicarp is cut off from the remainder by the formation of a transverse septum. The basal cell of the archicarp is called the *suspensor*, and the thicker apical cell the *gamete*. The two gametes are at first separated by their respective cell-walls, but these soon dissolve, allowing the protoplasm of the two to mingle, and a single cell or zygospore results, which grows for some time at the expense of the protoplasm originally contained in the two suspensors. The zygospore soon becomes clothed with a thick cell-wall, which is usually brown and warted or spiny when mature. Zygospores are formed amongst the mass of vegetative hyphæ, and are not so conspicuous as the gonidial form of reproduction, and unless specially sought after are likely to be overlooked. Depending on the species the two archicarps may originate from two branches springing from the same hypha or from two approximate hyphæ not in close morphological union.

De Bary states that in *Rhizopus nigricans* the two gametes and suspensors differ in size and other particulars. In *Syncephalis nodosa* the two archicarps coil round each other. In several species belonging to the *Mucorini* it sometimes happens that the two gametes, which under normal conditions coalesce to form a zygospore, remain distinct, or in

other cases only one archicarp is produced, yet the separate gametes develop into bodies resembling zygosporcs in structure and germination, proving that conjugation or the blending of protoplasm from two originally distinct cells is not indispensable for the formation of bodies morphologically and functionally indistinguishable from normally produced zygosporcs. Such bodies are called *azygosporcs*. Zygosporcs are usually *resting-sporcs*, that is, they possess the power of remaining in a dormant condition for some months before germination takes place. When both gonidia and zygosporcs are produced by a species, the general rule is that the gonidia appear first and germinate at once, thereby adding greatly to the number of individuals. This mode of increase continues throughout the summer; but such gonidia are not resting spores, and do not survive through the winter to produce new individuals the following spring, but towards the autumn the gonidial phase is arrested, and the formation of zygosporcs commences. These remain passive during the winter as resting-sporcs, and on germinating the following spring, produce bodies which find their way on to the special host, and produce in turn the gonidial phase. When zygosporcs are not produced, permanent mycelium often enables the fungus to survive the winter period. The most perfect sexual organs met with in the division characterized by the formation of oosporcs are developed as follows. The oogonia originate as spherical swellings at the tips or intercalary portions of the aseptate hyphæ. After reaching considerable size and becoming filled with dense protoplasm



containing numerous drops of oil, these swellings or oogonia are cut off from continuity with the cavity of the hypha by a septum if terminal, or by a septa on each side of the oogonium when intercalary. At this stage of development the protoplasm of the oogonium becomes differentiated, the denser portion along with the oil drops forms a sphere in the centre—the *oosphere*—which is furnished with a delicate membrane, and is surrounded by a layer of hyaline protoplasm, known as *periplasm*. Contemporaneous with the development of the oosphere the antheridium is formed, which is the swollen apex of a lateral branch, springing from the hypha bearing the oogonium at a short distance below the latter. The antheridium when fully developed is more or less elliptical or obovate, much smaller than the oogonium, richly filled with granular protoplasm, and cut off from the cavity of its supporting hypha by a septum. When the oosphere is formed the antheridium comes in contact with the oogonium, and at the point of contact sends a thin tube through the wall of the oogonium, which continues to grow until it reaches the surface of the oosphere. During the growth of the *fertilization-tube* the protoplasm of the antheridium undergoes differentiation into a central dense mass, the *gonoplasm*, and a thin peripheral portion. The gonoplasm passes along the *fertilization-tube*, through an opening formed at its apex, and mingles with the protoplasm of the oosphere, which at once secretes a thick cellulose wall, and is known as the *oospore*. Modification of the above method takes place in different species and genera, for instance, sometimes several oospheres are

formed in the oogonium; several antheridia are also frequently present. In some species of *Pythium* the gonoplasm can be distinctly seen to enter the oosphere, whereas according to De Bary, in the genus *Phytophthora*, only a very minute quantity of protoplasm passes from the antheridium into the oosphere, and this portion is not previously differentiated into gonoplasm, while in the *Saprolegnieæ*, according to the same author, the fertilization-tubes of the antheridia pierce the wall of the oogonia as in *Pythium*, and come in contact with the oospheres, but never open at the apex, hence no protoplasm passes from the antheridium into the oogonium; in other words, fertilization does not take place, nevertheless, the oospheres germinate as usual.

In some species, as *Pythium de Baryanum*, the oospores on germination put out a tube which directly branches and forms a mycelium, which again produces oogonia. In other instances, as in *Cystopus candidus*, the germinating oospore produces zoospores, which after a short period of activity become passive and germinate, giving origin to a mycelium which produces oogonia. In a third group, including *Pythium gracile*, some of the oospores give origin to germ-tubes directly, whereas others produce zoospores. The gonidial form of reproduction varies considerably in different genera. A peculiar habit, characteristic of *Saprolegnia*, but met with also in certain species of *Pythium*, is as follows. The *zoosporangia* are terminal cells separated from the cavity of the hypha by a septum. After the zoogonidia have escaped from the zoosporangium through an opening formed at the apex,

the hypha or stem grows up through the empty zoosporangium, and develops into a second, which in like manner may eventually enclose a third, and so on, hence in old specimens it is not unusual to see two or more empty zoosporangia one within another. In other species the second zoosporangium growing through the first is supported on a lengthened hypha or stem, and consequently carried outside the first.

In the *Mucorini* the erect hyphæ supporting the sporangia are called *sporangiophores*. The *Phycomycetes* are all minute fungi, and would be included in the category known as microscopic fungi, yet the mycelium in many species forms felt-like patches, often extending for several inches, and in *Phycomyces nitens* the sporangiophores, although slender, are often several inches long. The species of *Mucorini* are saprophytic on decaying vegetable or animal substances; the *Peronosporæ* are parasitic in the tissues of flowering plants; the species of *Saprolegnia* are aquatic saprophytes, whereas the *Entomophthoræ* are mostly met with on insects.

### PHYCOMYCETES.

Fungi with aseptate mycelium, parasitic on plants or animals, or saprophytes, aerial or aquatic; sexual mode of reproduction by oogonia and antheridia, or by conjugation of morphologically similar branches; asexual mode of reproduction by gonidia or zoogonidia.

*Phycomycetæ*, De Bary, in Fuckel's Symb. Myc. p. 66; Sacc. Syll. vii. p. 181; Brefeld, Mykol. Heft. vii. p. 274.

*Analytical Key to Families.*

A. Hyphæ well developed.

I. MUCORACEÆ.

Hyphæ producing sporangia; asexual organs of reproduction, gonidia produced in sporangia and chlamydogonidia; sexual form, zygosporos.

Aerial fungi; developing on various decaying organic substances.

II. PERONOSPORACEÆ.

Hyphæ frequently branched, bearing zoogonidia, or passive gonidia that germinate directly; asexual organs of reproduction, gonidia; sexual, oosporos.

Aerial fungi; endoparasitic on living plants, more especially on the leaves.

III. SAPROLEGNIACEÆ.

Hyphæ bearing zoogonidia; asexual reproduction by zoogonidia; sexual by antheridia and oogonia, producing oosporos.

Aquatic fungi; growing on fish, insects, or aquatic plants.

IV. ENTOMOPHTHORACEÆ.

Hyphæ bearing gonidia; asexual reproduction by gonidia and by thick-walled resting spores; sexual by zygosporos.

Aerial fungi; developing in living insects, and after the insect's death emitting gonidiophores; rarely parasitic or saprophytic on plants.

B. Hyphæ obsolete.

V. CHYTRIDIACEÆ.

Sporangia alone, without mycelium; asexual re-

production by zoogonidia; sexual mode by zygo-spores.

Either aerial and endoparasites in plants, or aquatic and parasitic on algæ, fungi, or infusoria.

## VI. PROTOMYCETACEÆ.

Filiform hyphæ soon disappearing; sporangia very thick-walled.

Aerial fungi; endoparasitic in plants.

### *Analytical Key to Subfamilies.*

#### FAM. 1. MUCORACEÆ.

A. Columella present, hyphæ of mycelium stout, not anastomosing.

\* Sporangium containing many gonidia.

1. Subfam. *Piloboleæ*.

Tunic distinct from sporangium.

2. Subfam. *Mucoreæ*.

Tunic homogeneous with sporangium, entirely disappearing or persistent.

\*\* Sporangium containing only one gonidium.

3. Subfam. *Chætocladiæ*.

B. Columella absent; hyphæ of mycelium slender, anastomosing.

4. Subfam. *Mortierelleæ*.

Sporangium globose.

5. Subfam. *Syncephalideæ*.

Sporangium cylindrical.

#### SUBFAM. 1. PILOBOLEÆ.

Tunic of sporangium diffuent at the base; sporangium polysporous; mycelium not anastomosing.

### *Analysis of the Genera.*

*Pilobolus*. Sporangia elastically projected.

*Pilaira*. Sporangia elevated on a long weak stem.

**Pilobolus, Tode.**

Sporangiferous hyphæ erect, aseptate, swollen at the apex, distilling minute drops of water, cut off from the vegetative mycelium by a transverse septum at the base; sporangium depresso-globose, black, covered with the minutely warted tunic, ejected at maturity.

*Pilobolus*, Tode, Fung. Meckl. p. 41; Sacc. Syll. vii. p. 184.

Minute fungi, growing chiefly on the dung of various animals.

Gregarious, or densely crowded, appearing as minute crystalline threads tipped with yellow. As development proceeds a certain amount of water is transpired, which collects in minute drops on the stem. The sporangium at maturity is ejected into the air with its contained spores.

*Pilobolus crystallinus*, Tode (fig. 57).

Sporangiferous hyphæ slender, pellucid, tinged yellow, secreting minute drops of water, apex ventricoso-globose; sporangia hemispherical, 270-300  $\mu$  diameter, black, externally with minute warts arranged in a more or less reticulate manner; columella bluish-black; spores elliptical, epispore thin, very pale yellow, 7-10  $\times$  5-6  $\mu$ .

*Pilobolus crystallinus*, Cke. Hdbk. n. 1894; Grove, Mon. Pilob. p. 33, t. iv. f. 16.

*Eucrystallinus*, l.c. p. 34; Sacc. Syll. vol. vii. n. 592.

On horse and cow dung. Very common.

Gregarious, or often densely crowded, sporangiferous hyphæ  $\frac{1}{4}$ — $\frac{2}{3}$  in. high.

*Pilobolus Kleinii*, Van Tiegh.

Sporangiferous hyphæ pellucid, inflated at the apex, slender, secreting minute drops of water; sporangia blackish with purple tinge, spherico-depressed, cuticle minutely warted, columella conical; spore rather irregular in form, spherico-ellipsoid, orange yellow,  $12-15 \times 6-9 \mu$ .

*Pilobolus Kleinii*, Van Tiegh.; Grove, Mon. Pilob. p. 35, pl. iv.

*Pilobolus roridus*, Currey, Journ. Linn. Soc. vol. i., p. 162, pl. ii.; Sac. Syll. vii. 593.

*Pilobolus roridus*, Cke. Hdbk. n. 1895, fig. 301 (copied from Currey's, fig. Journ. Linn. Soc., vol. i. pl. ii.).

On cow dung. Local.

Gregarious or densely crowded, appearing as minute, yellow, erect hyphæ, which eventually reach a height of over  $\frac{1}{4}$  inch. Distinguished by the large orange spores.

*Pilobolus roridus*, Pers.

Sporangiferous hyphæ slender, elongated, semi-pellucid, secreting minute drops of water, spherical above; sporangia hemispherico-depressed,  $180-200 \mu$  diameter, brown, columella convex; spores elliptical, pale yellow,  $6-8 \times 3-4 \mu$ .

*Pilobolus roridus*, Pers.; Syn. Fung. p. 118; Grove, Mon. Pilob. p. 36, t. vi. f. 4—6; Sacc. Syll. vii. 594.

On dung of various mammals. Not uncommon.

Gregarious, exceeding  $\frac{1}{2}$  inch in height.

*Pilobolus longipes*, Van Tiegh.

Sporangiferous hyphæ filiform, long, subhyaline, apex globose, at the base becoming inflated into a subcylindrical bulb of a clear yellow colour, and 1.5—2 mm. long; sporangium globose, blackish-blue, .5 mm. across; columella conical, tinged blackish-blue; spores irregularly globose or broadly elliptical, epispore thick, and feebly tinged with dingy blue, 10-12 or  $11 \times 13 \mu$ .

*Pilobolus longipes*, Van Tiegh. Ann. Sci. Nat. ser. vi. vol. iv. p. 338, pl. 10, figs. 11-15; Grove, Mon. Pilob. p. 35, t. vi. f. 1; Sacc. Syll. vii. 595.

On dung of various animals. Rare.

The largest species of the genus, sporangiferous hyphæ  $\frac{3}{4}$ —1 inch high. The large size, globose sporangium, and elongated inflation at the base of the hypha characterize the present species.

*Pilobolus Œdipus*, Mont.

Sporangiferous hyphæ short, rather thick, inflated at the tip, base bulbous, yellow; sporangia spherical, up to  $400 \mu$  across, covered with a violet-brown cuticle; columella cylindrico-conical; spores spherical, often unequal, even in the same sporangium, epispore thick, almost colourless, 16-18  $\mu$ .

*Pilobolus Œdipus*, Grove, Mon. Pilob. p. 33, t. iv. ff. 14—15; Sacc. Syll. vii. n. 598.

On human dung. Not common.

Sporangiferous hyphæ short, 1—2 mm. Agrees with *P. longipes* in the globose sporangium, but dis-



tinguished by its smaller size, and the globose, not elongated, inflation at the base of the hypha.

### **Pilaira, Van Tiegh.**

Sporangiferous hypha without a swelling at the apex, and without a transverse septum at the base, becoming considerably elongated and elevating the sporangium at its apex; cuticle of upper portion of sporangium thick, indurated; columella present, sporangium not projected as in *Pilobolus*.

*Pilaira*, Van Tiegh. Ann. Sci. Nat. ser. vi. vol. i. p. 50; Grove, Journ. Bot. vol. xiii., n. s. p. 132.

Distinguished from the genus *Pilobolus* by the sporangium not being projected, but elevated on a long stem, which soon disappears.

#### *Pilaira anomala*, Schroet. (figs. 1-5).

Sporangiferous hyphæ cylindrical, slender, elongated, aseptate, often recurved at the apex, hyaline, flexuous; sporangia at first spherical, then hemispherical, up to  $250\ \mu$  diameter, black, minutely warted; columella hemispherical, hyaline, up to  $120\ \mu$  across; spores equal, elliptical,  $5-12 \times 6-7\ \mu$ , subhyaline or tinged yellow; zygospores  $100-120\ \mu$  diameter, epispore black, even.

*Pilaira anomala* (Ces.), Schroet. Krypt. Fl. Schles. Pilze, p. 211; Sacc. Syll. n. 606.

*Pilaira Cesatii*, Van Tiegh. Ann. Sci. Nat. ser. vi. vol. i. p. 52, pl. 1, figs. 14—24; Grove, Mon. Pilob. p. 37, t. 6, ff. 7, 8.

On dung of various animals. Local.

Distinguished by the very long thin stem, which

eventually becomes flexuous and collapses. From 2—4 in. high.

*Pilaira dimidiata*, Grove (fig. 131).

Sporangiferous hyphæ short, slender, equal, becoming curved at the apex; sporangium black; columella almost as large as the sporangium, but not quite so wide, slightly coloured; spores very pale yellow, elliptic-oblong,  $12-14 \times 5-6 \mu$ .

*Pilaira dimidiata*, Grove, Journ. Bot. vol. xiii. n. s. p. 132, tab. 245, f. 7; Sacc. Syll. vii. 608.

*Pilaira inosculans*, Grove, Midl. Nat. vol. vi. p. 119.

On dog's dung. Rare. Closely allied to *P. anomala*, but distinguished by its smaller size, shorter stem, not more than  $\frac{1}{4}$  in. high, and large columella.

### Endodromia, Berk.

Sporangium very delicate, perforated by the stem, which continues as a slender columella, filled with branched radiating threads and globose spores.

*Endodromia*, Berk.; Hook. Journ. iii. p. 79; Sacc. Syll. vii. p. 190.

No specimen exists in Berkeley's herbarium at Kew, hence no further information can be given. Berkeley says, "within each sporidium is a single globose nucleus, which moves about within its walls with the greatest activity, from which circumstance I have framed the generic name."

*Endodromia vitrea*, Berk. (figs. 60-61).

Stem straight, slightly thinner upwards, penetrat-

ing the globose sporangium as a long slender columella; sporangium delicate, soon breaking up, filled with branched radiating threads and globose spores.

*Endodromia vitrea*, Berk.; Hook. Journ. iii. p. 79, tab. 1, C.; Cooke, Hdbk. n. 1897, f. 303 (copied from Berkeley); Sacc. Syll. vii. n. 614.

On fallen branches, especially ash. Rare. Exceedingly minute. Stem always, I believe, quite straight, slightly attenuated upwards, running completely through the globose peridium; the portion within the peridium is very slender. (Berk. l.c.)

#### SUBFAM. 2. MUCOREÆ.

Mycelium not anastomosing; sporangia polysporous, furnished with a columella, wall homogeneous.

#### *Analysis of the Genera.*

A. Vegetative mycelium well developed.

§ Sexual branches equal.

*Mucor*. Sexual branches straight.

*Phycomyces*. Sexual branches arcuate, spinulose.

*Spinellus*. Sexual branches arcuate, not spinulose.

· *Sporodinia*. Hyphæ dichotomous.

§§. Sexual branches unequal.

*Helicostylum*. Sporangiphores curved.

*Thamnidium*. Sporangiphores dichotomous.

B. Vegetative mycelium rudimentary.

*Rhizopus*. Sporangiphores fasciculate.

*Circinella*. Sporangia dehiscing transversely, lower portion persistent.

#### **Mucor, Micheli.**

Mycelium creeping, often copious, colourless, septate; sporangiferous hyphæ erect, simple or

branched, often transversely septate; sporangium globose or subglobose, columella present; sexual branches straight.

*Mucor*, Mich. Nov. Gen. Plant. p. 215; Sacc. Syll. vii. p. 190.

The species of *Mucor* usually form a more or less dense vegetative layer of mycelium, the *hyphasma*, on putrid or decaying organic matter. The sporangiferous hyphæ are erect, and the sporangium usually globose. Zygosporangia are comparatively rare, and in most species are up to the present unknown.

A. *Sporangia coloured at maturity.*

*Mucor mucedo*, Linn.

Sporangiferous hyphæ simple, erect, dirty yellow or brownish, sporangia spherical, minute, yellowish or greenish-grey, dusky brown when dry, very minutely rough; columella ovoid, yellowish-brown; spores elliptical,  $6.9 \times 3.4 \mu$ , tinged yellow; zygosporangia spherical, episporangia black, with large irregular protuberances,  $99-214 \mu$ .

*Mucor mucedo*, Linn. Sp. pl. ii. 1655; Sacc. Syll. vii. n. 615; Cke. Hdbk. n. 1884.

On various decaying organic substances, as fruit, paste, preserves, &c., also on dung. Common. Stem  $\frac{1}{2}$ —1 in. long, very slender, at length collapsing.

Var. *caninus*.

Sporangiferous hyphæ simple, whitish, elongated, lax, erect; sporangium spherical, at first yellow, then blackish-brown, minute, columella globose, yellowish; spores elliptical or elliptic-ovoid,  $7.13 \times 8.9 \mu$ , subhyaline.

*Mucor caninus*, Pers. Obs. myc. i. p. 96, t. 6, f. 3; Cke. Hdbk. n. 1885, fig. 300.

On dung of dogs and cats. Common.

*Mucor lateritius*, Cke. and Mass. (figs. 70a-71).

Mycelium aseptate, forming a continuous, dense, dry, bright-brown felt, spreading over the substratum; sporangiophores numerous, aseptate, erect, straight or flexuous, once furcate or rarely simple, bright-brown; sporangia spherical, separated from the cavity of the sporangiophore by a septum, slightly convex upwards, wall brown, very thin, smooth, dehiscing by an irregular transverse slit, the upper portion falling away, the lower portion persistent and pendulous; 40-45  $\mu$  diameter; spores subglobose, pale brick-red, smooth, 12  $\times$  9-10  $\mu$ ; sexual conditions are unknown.

*Mucor lateritius*, Cooke and Masee, Grevillea, vol. xvii. p. 3 (1888).

On putrid potatoes. Rare.

Sporangiferous hyphæ or sporophores 120-150  $\times$  7-8  $\mu$ . The present species is not a good *Mucor*, neither does it agree in all points with any described genus, but until something is known of the sexual stage it is not advisable to remove it from the genus under which it was originally described. Some features suggest an affinity with *Sporodinia*.

*Mucor stercoreus*, Link.

Sporangiferous hyphæ erect, simple, yellowish; sporangium globose, yellowish then black with shades of yellow; columella oblong, constricted at the base;

spores elliptical,  $15 \times 6-7 \mu$ , sometimes subglobose, at length brown.

*Mucor stercoreus*, Link. Sp. v. p. 20; Sacc. Syll. vii. 616.

*Hydrophora stercorea*, Tode, F. M. p. 6.

In human dung. Rare.

*Mucor subtilissimus*, Berk.

Mycelium creeping; sporangiferous hyphæ erect, branched, branches short, spreading, each terminated by a minute, spherical sporangium; spores elliptic-oblong.

*Mucor subtilissimus*, Berk. Hort. Journ. iii. p. 98, ff. 1—5; Cke. Hdbk. n. 1893; Sacc. Syll. vii. 625.

On mildewed onions, developed from *Sclerotium cepavorum*. Rare. Exceedingly minute. No specimen exists in Berkeley's herbarium, consequently the size of the spores cannot be given.

*Mucor clavatus*, Link.

Byssoid, white, vegetative mycelium delicate, aseptate; sporangiferous hyphæ solitary, not fasciculate, simple, thickened into an obconic form at the apex, at this point  $12-18 \mu$  across, brownish-olive; sporangia spherical, smooth, smoky, very thin,  $100-180 \mu$  diam., columella cylindrical, apex rounded; spores spherical, or broadly elliptical, size variable,  $8-21 \mu$  diameter, smoky-brown, epispore minutely striate.

*Mucor clavatus*, Cke. Hdbk. n. 1887; Sacc. Syll. vii. n. 626.

On rotting fruits. Not common.

The *hyphasma*, or vegetative portion of the mycelium, forms a thin *byssoid* or cotton-wool like stratum, from which scattered sporophores, or *sporan-*

*giferous hyphæ*, ascend. Known by the latter being swollen at the apex and brown in colour. Minute.

*Mucor succosus*, Berk.

Hyphasma forming small pulvinate ochraceous tufts; sporangiferous hyphæ erect, very delicate, colourless, equal; sporangia globose, yellow, then brownish-olive; columella very small; spores colourless, elliptical  $5 \times 3.3.5 \mu$ .

*Mucor succosus*, Berk. Ann. Nat. Hist. vol. vi. p. 443, tab. xii. f. 15 (no. 225); Cke. Hdbk. n. 1889; Sacc. Syll. vii. 628.

On cut stumps of *Aucuba Japonica*. Rare.

Forming spongy ochraceous tufts,  $\frac{1}{4}$ — $\frac{1}{2}$  in. across; sporangia very numerous.

*Mucor amethysteus*, Berk.

Hyphasma dense, expanded, white; sporangiferous hyphæ simple; sporangia depresso-globose, passing from white through yellow to violet-brown; spores irregularly globose, dingy violet,  $7-11 \mu$ .

*Mucor amethysteus*, Berk. Eng. Fl. vol. v. p. 332; Cke. Hdbk. n. 631; Sacc. Syll. vii. n. 637.

On decaying fruit. Rare.

Sporangia small, stem about  $\frac{1}{4}$  in. high. Distinguished by the violet spores.

*Mucor delicatulus*, Berk.

Hyphasma forming a very delicate stratum; sporangiferous hyphæ short; sporangia globose, minute, yellow; spores globose, colourless,  $4 \mu$  diam.

*Mucor delicatulus*, Berk. Eng. Fl. vol. v. p. 332; Cke. Hdbk. n. 1891; Sacc. Syll. vii. n. 657.

On rotting gourds. Rare.

Forming very delicate velvety patches barely visible to the naked eye.

*Mucor tenerrimus*, Berk.

Scattered, minute, wholly colourless and pellucid; stem flexuous upwards, apex clavate; sporangium globose, colourless; spores elliptic-oblong, colourless,  $6 \times 7 \mu$ .

*Mucor tenerrimus*, Berk. Outl. p. 7; Cke. Hdbk. n. 1892; Sacc. Syll. vii. 638.

*Hydrophora tenerrima*, Berk.; Hook. Journ. 1841, vol. iii. p. 78. t. 1, f. B.

On sticks in woods. Rare.

“Scarcely visible to the naked eye, and when examined with a good pocket lens exhibiting nothing more than a short, very slender, white thread, with a watery, colourless globule seated on its apex. Under a high magnifier the stem is found to be a little flexuous above, and to end in a clavate swelling, beyond which is the globose columella, from the base of which is deflected all round over the apex of the stem a delicate frill, which at first formed a portion of the pendulum, and by its rupture leaves a large circular aperture at its base. I am not able to state positively whether there is any organic connection between the tip of the stem and the columella after the rupture has taken place, or, whether they are kept in apposition by means of the frill, though I suspect that such an union does exist. Peridium quite smooth, consisting of two membranes, between which there is often a considerable space, though they are sometimes in close contact. At the place where it separates from the portion which remains attached to the



columella, there is often a ring of considerable size. The cavity between the second membrane and the columella is filled with elliptic sporidia, some of which occasionally adhere to the stem. (Berk. l.c.).

The above account shows clearly that the present species is not a *Mucor* as at present defined, but rather belongs to the *Pilobolæ*, and further, appears to be distinct from every known genus, but it is advisable to allow the question to remain open until the fungus is met with again. No structural details can be made out from Berkeley's specimen.

*Mucor pruinosis*, B. and Br.

Minute, snow-white; sporangia reticulated, globose; spores irregular, 17-30  $\mu$ .

*Mucor pruinosis*, B. and Br., Ann. Nat. Hist. n. 1495.

Forming an exceedingly thin, snow-white bloom on soil. Rare.

I can find no trace of the *Mucor* on the soil on which it originally occurred, consequently no type specimen exists, and it is doubtful whether, from the above brief description, the species will ever be again recognized.

B. *Sporangia* colourless at maturity.

*Mucor hyalinus*, Cooke.

Hyphasma creeping, profuse; sporangiferous hyphæ erect, simple, or sometimes branched; sporangia globose, minute, colourless; spores elliptical, colourless,  $4 \times 2.5-3 \mu$ .

*Mucor hyalinus*, Cke. Hdbk. n. 1890; Sacc. Syll. vii. n. 682.

On leaves of box (*Buxus*). Not uncommon.

Forming an exceedingly thin white film on the under surface of the leaves. Cooke first detected the present species mixed with *Penicillium roseum*, which he considers to be the gonidial form of the *Mucor*, but there is no evidence of such connection, unless the fact of the two species being found on the same substratum is considered as such, which cannot possibly be accepted.

### **Phycomyces, Kunze.**

Sporangiferous hyphæ at first erect, simple, aseptate, shining, often very long; sporangia spherical or piriform, very delicate, brown, ruptured at maturity, and the basal portion remaining like a frill round the columella. Branches of zygospore arcuate and furnished with rigid forked spines.

*Phycomyces*, Kunze, Mykol. ii. p. 113; Sacc. Syll. vii. p. 204.

*Mucor*, Berk. Outl. p. 307; Cke. Hdbk. p. 630.

Remarkable for the dry glistening nature of the hyphæ. Distinguished from *Mucor* by the base of the sporangium remaining as an irregular ring or frill round the columella, and by the *arcuate*, or arched, spiny branches of the zygospore.

### *Phycomyces nitens*, Kunze.

Hyphasma dense, effused, dry, olive-brown, shining; sporangiferous hyphæ often springing in clusters of 3—4 from a mycelial hypha, when 1—2 are usually sterile, brown, shining, decumbent, aseptate; sporangia globose, opaque, black; columella spherical then

becoming cylindrical; spores elliptic-oblong, pale-olive,  $20-30 \times 10-14 \mu$ . Zygosporangium globose, brown,  $\frac{1}{3}$  mm. diam.; branches of zygosporangium arcuate, with dichotomously divided spines.

*Phycomyces nitens*, Kunze, Mykol. Hefte. ii. p. 113; Sacc. Syll. vii. 696.

*Mucor phycomyces*, Berk. Outl. p. 407; Cke. Hdbk. n. 1882.

On fat and grease of various kinds; also on dung. Local.

Often forming extensive olive-brown dry patches, with a remarkable glistening appearance; sporangiferous hyphae same colour and shiny appearance, from 3—8 in. long, weak, and soon *decumbent* or drooping.

### **Spinellus, Van Tiegh.**

Mycelium white, then olive-brown, branched, some of the branches furnished with spiny outgrowths; sporangiferous hyphae erect, simple, becoming olive-brown. Sexual branches equal, approaching each other at the base, then diverging, and again approaching at the tips.

*Spinellus*, Van Tiegh. Ann. Sci. Nat. 1875, p. 66; Sacc. Syll. vii. p. 205.

*Mucor*, Cke. Hdbk. p. 630.

Distinguished by the branches being furnished with numerous spreading spine-like branchlets.

*Spinellus fusiger*, Van Tiegh. (figs. 74-77).

Mycelium branched, branches spiny, aseptate; sporangiferous hyphae erect, cylindrical, base swollen, colourless, then brown; sporangia globose, hyaline,

then blackish, columella cylindrical, thick, blackish-blue; spores elliptic-fusiform, or elliptic-oblong, very pale olive,  $35-40 \times 10-12 \mu$ . Zygosporangium barrel-shaped,  $200-400 \mu$  diam., blackish-brown.

*Spinellus fusiger*, Van Tiegh. Ann. Sci. Nat. 1875, p. 66, t. 1, figs. 29—37; Sacc. Syll. vii. 699.

*Mucor fusiger*, Cke. Hdbk. n. 1886.

On decaying agarics. Not common. Forming a dry, shining, olive-brown felt, somewhat resembling *Phycomyces nitens*, but distinguished by the spinose mycelium.

### Sporodinia, Link.

Sporangiferous hyphæ septate, repeatedly dichotomously branched above; sporangia terminal on the ultimate branchlets. Zygosporangium-forming branches, smooth, straight.

*Sporodinia*, Link, Sp. pl. vi. 1, p. 94; Sacc. Syll. vii. p. 206.

*Sporodinia*, Cke. Hdbk. p. 635 (gonidial stage).

*Syzygites*, Cke. Hdbk. p. 636 (sexual condition).

Distinguished amongst its allies by the regularly bifurcating branches of the sporangiferous hyphæ, and by the straight, smooth branches of the zygosporangium.

*Sporodinia aspergillus*, Schröt. (figs. 6-11).

Tufts, at first white, then ochraceous; sporangiferous hyphæ erect, numerous, branched above 4—6 times in a dichotomous manner, branchlets spreading, each terminating in an obovate, pellucid sporangium; columella hemispherical; spores very unequal in size, subglobose, colourless, then often tinged olive,  $15-30 \mu$ . Mycelium of sexual stage olive brown,

branched; zygospor-forming branches straight, smooth, clavate; zygospor sub-spherical, blackish, brown, warted, 300-350  $\mu$  diameter.

*Sporodinia aspergillus*, Schröt. Kr. Fl. Schl. p. 209 ; Sacc. Syll. vii. 702.

*Sporodinia dichotoma*, Cke. Hdbk. n. 1898, fig. 704 (gonidial form).

*Sporogites megalocarpus*, Cke. Hdbk. n. 1900, fig. 306 (sexual form).

*Mucor ramosus*, Cke. Hdbk. n. 1883.

On decaying fungi. Not common.

The gonidial state is recognized by the repeatedly forked or dichotomously divided tips of the sporangio-phores, and the obovate sporangia. The sexual condition resembles superficially *Phycomyces nitens* and *Spinellus fusiger*, but distinguished by the smooth, straight, zygosporic branches.

### **Helicostylum, Corda.**

Sporangiferous hyphæ erect or decumbent, branched; sporangium terminating main stem, large, spherical, columella present; branches spirally re-curved, terminated by small globose or piriform sporangiola, columella minute or absent. Spores similar in the two forms of sporangia.

*Helicostylum*, Corda, Ic. Fung. pt. v. pp. 17 and 55 ; Sacc. Syll. vii. p. 209 ; Cke. Hdbk. p. 936, fig. 408.

Distinguished by the curved branches.

*Helicostylum elegans*, Corda (figs. 15a-17).

Sporangiferous hyphæ erect, elongated, branched; sporangium terminating main stem, globose, large;

columella stout, elongated, spores numerous; branches scattered, spirally recurved, usually terminated by small globose sporangia (sporangiola); columella minute; spores few, resembling in size and form those of the large terminal sporangium, colourless, elliptical,  $7.9 \times 5.6$  p.

*Helicostylum elegans*, Corda, Ic. Fung. pt. v. pp. 17 and 55, tab. ii. fig. 23; Cke. Hdbk. p. 936, fig. 408; Sacc. Syll. vii. n. 708.

On various decaying organic substances. Rare.

Forming minute whitish tufts, sporangiferous hyphæ  $\frac{1}{2}$ —1 in. high. Distinguished by the spirally coiled branches; but these are sometimes absent, when the simple stem with its terminal sporangium closely resembles *Mucor mucedo*.

*Helicostylum nigricans*, Van Tiegh. (figs. 18—21).

Sporangiferous hyphæ erect, branched, white, then dusky, sporangium terminating the main stem, large, globose; columella ovoid; branches verticillate, short, slender, tips recurved, sporangiola spherical, columella minute; spores alike in the two forms of sporangia, colourless, elliptical,  $8.9 \times 5.6$ .

*Helicostylum nigricans*, Van Tiegh. Ann. Sci. Nat. ser. vi. vol. iv. p. 374, pl. 13, figs. 79—83; Sacc. Syll. vii. n. 711.

On decaying organic matter. Rare.

Forming minute tufts, at first white, then blackish, sporangiferous hyphæ up to  $\frac{1}{4}$  in. high. Distinguished by the verticillate branches; when the latter are absent, as is sometimes the case, the fungus is difficult to separate from species of *Mucor*. The main hypha is

swollen at the points from which the verticillate branches spring.

### **Thamnidium, Link.**

Sporangiferous hyphæ scattered, erect, branched, rarely simple; sporangium terminating the main stem, large, globose, containing many spores; branches verticillate, twice or several times dichotomously divided, branchlets spreading, straight, terminated by small globose sporangiola, containing few, rarely only one spore.

*Thamnidium*, Link, Spec. Pl. i. p. 97; Sacc. Syll. vii. p. 211.

*Ascophora*, Cke. Hdbk. p. 629.

Minute, closely related to the genus *Helicostylum*, but distinguished by the repeated dichotomous branches, which are straight, and not spirally coiled or curved as in the last named genus.

### *Thamnidium elegans*, Link.

Sporangiferous hyphæ erect, branched; sporangium of primary hypha globose, brown, columella large, spores numerous; branches verticillate or solitary, repeatedly dichotomous, terminating in small, spherical sporangiola containing not more than ten spores, frequently fewer; spores of both forms of sporangia similar, elliptical, hyaline, rarely with a bluish tinge,  $8-10 \times 6-8 \mu$ .

*Thamnidium elegans*, Link, Obs. p. 45, t. ii. f. 45; Sacc. Syll. vii. n. 714.

*Ascophora elegans*, Cke. Hdbk. n. 1881.

On putrid organic substances, dung, &c. Local.

Forming minute, white, fugacious tufts; variable,

sometimes the lateral branches are entirely absent, when the fungus has been described as a *Mucor*. In other examples, the lateral branches are well developed and bear sporangiola, but when the large terminal sporangium is absent, this form has been described as a new genus, *Melidium*.

*Thamnidium verticillatum*, Van Tiegh. (figs. 33—35).

Minute; sporangiferous hyphæ erect, branched; sporangium at apex of primary hypha globose, incrustated with lime; columella cylindrical; branches verticillate, rather long, twice dichotomous near the end, branchlets spreading, ending in minute, globose, smooth sporangiola, with a minute, plano-convex columella; spores similar in the two forms of sporangia, spherical, hyaline, 5-6  $\mu$ .

*Thamnidium verticillatum*, Van Tiegh. Ann. Sci. Nat. ser. vi. vol. iv. p. 376, pl. 13, figs. 84—89; Sacc. Syll. vol. vii. n. 715.

On horse dung. Rare.

Forming minute tufts,  $\frac{1}{2}$ — $\frac{1}{3}$  in. high. The development varies as in *Thamnidium elegans*; sometimes the terminal large sporangium is suppressed, at other times the branches are absent, and when present the whorls vary from one to three. All these forms may often be found in the same tuft.

### **Rhizopus, Ehr.**

Hyphasma stoloniferous, straight or flexuous, giving off fasciculate, slender branched hyphæ from the under side, at those points corresponding to the origin of the fasciculate sporangiophores on the upper side, white, becoming blackish; sporangiferous hyphæ



straight or circinate at the apex, aseptate ; sporangia globose, with a membranaceous apophysis at the base ; spores numerous, generally coloured.

*Rhizopus*, Ehr. Nova Acta, x. p. 195 ; Sacc. Syll. vii. p. 212.

Distinguished by the stolon-like, creeping mycelium giving off fasciculate hyphæ from the under side, and fasciculate sporangiferous hyphæ from corresponding points of the mycelium.

*Rhizopus nigricans*, Ehr. (figs. 24, 25).

Sporangiferous hyphæ erect, usually in fascicles of 3—10, aseptate, springing from long, creeping, stolon-like hyphæ, that give off numerous rhizoids ; sporangia globose, blackish-olive, granular, columella hemispherical ; spores subglobose or broadly elliptical, grey,  $11 \times 14$  or  $11-13 \mu$ .

*Rhizopus nigricans*, Ehr. Nova Acta, x. p. 198. t. 11 ; Sacc. Syll. vii. n. 719.

On various decaying substances, as leaves, fruit, branches, &c. Local.

Forming thin spreading tufts, at first whitish, then blackish-olive, sporangiferous hyphæ  $\frac{1}{8}$ — $\frac{1}{3}$  in. high.

### **Circinella**, Van Tiegh. and Le Mon.

Sporangiferous hyphæ erect, branched ; sporangia globose, many spored, furnished with a columella and supported on recurved branches ; sporangia dehiscing in a circumscissile manner at the centre, basal half persisting ; spores globose.

*Circinella*, Van Tiegh. and Le Mon. Ann. Sci. Nat. ser. v. vol. xvii. p. 298 ; Sacc. Syll. vii. p. 215.

Agreeing with *Helicostylum* in having the branches bearing the sporangia curved at the tip, but differs in having only one kind of sporangium, and in the basal half of its wall remaining as a permanent frill round the columella.

*Circinella simplex*, Van Tiegh. (figs. 13, 14).

Sporangiferous hyphæ erect, becoming brown, with several short, spirally arranged branches, recurved at the tips, each one supporting a globose, bluish sporangium; columella conico-cylindrical, spores globose, colourless, 3-4  $\mu$ .

*Circinella simplex*, Van Tiegh. Ann. Sci. Nat. Hist. ser. vi. vol. i. p. 92, pl. 2, figs. 52—54; Sacc. Syll. vii. n. 731.

On dog's dung. Rare.

Forming minute tufts about  $\frac{1}{3}$  in. high, at first whitish, soon becoming brown.

### SUBFAM. 3. CHÆTOCLADIÆ.

Vegetative hyphæ not anastomosing; sporangia monosporous; columella present.

*Chætocladium*. The only known genus.

### **Chætocladium**, Fres.

Sporangiferous hyphæ erect, 3—5 times branched above, all the branches and branchlets acute and sterile at the tips; sporangia globose, warted, containing a single spore, springing in small clusters from the central portion of ternary lateral branchlets; spores smooth.

*Chætocladium*, Fres. Biétr. zur Mykol. p. 97; Sacc. Syll. vii. p. 220.

*Botrytis*, Cke. Hdbk. p. 591.

Distinguished by the much branched sporangio-phores having all the branchlets sterile and spine-like at the tips, and by the warted sporangia containing only one spore.

*Chaetocladium Jonesii*, Fres. (figs. 62, 63).

Sporangiferous hyphae erect, branched, main branches at right angles, verticillate, or often opposite, these are again divided once or twice in the same plane, all the branchlets with spine-like tips, the central branchlet of the ultimate ramification always barren, the lateral ones producing small clusters of sporangia from a swollen portion situated at some distance below the pointed tip; sporangia globose, one-spored, minutely warted, 60-120  $\mu$  in diameter; spores globose, smooth, bluish, 6-9  $\mu$ .

*Chaetocladium Jonesii*, Fres. Beitr. p. 97; Sacc. Syll. vii. n. 747.

*Botrytis Jonesii*, Cke. Hdbk. n. 1772.

On dung of various animals. Local.

Forming minute tufts, often mixed with *Mucor mucedo*, on which it is supposed to be to some extent parasitic. All the branches are swollen at the point of origin, and spine-like at the tips.

*Chaetocladium Brefeldii*, Van Tiegh. (fig. 130).

Sporangiferous hyphae erect, branched, 3-4 times verticillately-branched, sporangia spherical, bluish, 30-50  $\mu$  diameter; spores globose, 2-4  $\mu$  diameter; zygosporoes globose, pale brown, 40-50  $\mu$ .

*Chaetocladium Brefeldii*, Van Tiegh. and Le Mon.; Ann. Sci. Nat. ser. v. vol. xvii. p. 342, t. 23, figs. 71-79; Sacc. Syll. vii. 748.

On dung. Rare.

Mixed with *Mucor mucedo*. Closely resembling *Chaetocladium Jonesii* in general appearance, but distinguished by the smaller sporangia and spores.

SUBFAM. 4. MORTIERELLEÆ.

Vegetative hyphæ slender, anastomosing; sporangia globose, polysporous; columella absent.

*Mortierella*. The only British genus.

**Mortierella, Coemans.**

Mycelium slender, dichotomously branched and anastomosing; sporangiferous hyphæ erect, often originating in small clusters, thick at the base and tapering upwards, simple or branched, branches terminated in a single spherical sporangium without a columella. Zygosporoes and chlamydogonidia present in some species.

*Mortierella*, Coemans, Bull. Ac. Belg. ser. ii. part i. p. 536, t. 15.; Sacc. Syll. vii. p. 220.

The leading features of the present genus are the anastomosing mycelium, and the absence of the columella in the many-spored sporangium. The branches are frequently arranged in a verticillate or corymbose manner, and taper upwards.

*Mortierella polycephala*, Coemans (figs. 29, 30).

Mycelium aseptate, dichotomously branched, branches elongated, very slender; sporangiferous hyphæ erect, fasciculate, fusiform, 250  $\mu$  high, branched in a racemose manner; sporangia globose, hyaline, wall diffuent, containing 4—20 ovate or globose hyaline gonidia, 9-14  $\mu$  diameter. Chlamy-

dospores supported singly or arranged in a verticillate manner on long, slender hyphæ springing from the mycelium, globose, echinulate,  $20\ \mu$ .

*Mortierella polycephala*, Coemans, Bull. Ac. Belg. ser. ii. part i. p. 536, t. 15; Sacc. Syll. vii. 755; Van Tiegh. Ann. Sci. Nat. ser. v. vol. xvii. p. 348, t. 24, figs. 80—89.

On decaying fungi and on dung. Rare.

Van Tieghem has shown by cultures that the present species is very variable in the mode of branching, sometimes producing the apical sporangium only. The mode of branching cannot be relied upon as a specific character.

*Mortierella candelabrum*, Van Tiegh. and Le Mon.

Mycelium white, thin, dichotomously branched; sporangiferous hyphæ erect, base incrassated, becoming very slender upwards, branches usually arranged in a corymbose manner, incrassated at the base, sporangia globose, gonidia globose, hyaline, variable in size,  $4\text{--}10\ \mu$  diameter; chlamydogonidia interstitial or terminal, on short lateral branches of the mycelium, spherical, elliptical, or irregular, up to  $40\ \mu$  diameter.

*Mortierella candelabrum*, Van Tiegh. and Le Mon. Ann. Sci. Nat. ser. v. vol. xvii. p. 348, pl. 24, figs. 99—102; Sacc. Syll. vii. 761.

On decaying organic substances.

This species has not been met with in Britain, but is introduced on account of the following, which is considered as a variety of the present species, having been met with by Mr. Grove near Birmingham.

Var. *minor*, Grove. Sporangiferous hypha branched

from near the base, with long ascending subulate branches, after the fashion of a candelabrum. Gonidia spherical, smooth, hyaline, 10-12  $\mu$  diameter.

*Mortierella candelabrum*, Van Tiegh. and Le Mon., var. *minor*, Grove, Journ. Bot. vol. xiv. n. ser. p. 131, tab. 256, fig. 1.

On rotten wood.

Height,  $\frac{1}{5}$ - $\frac{1}{3}$  mm. Van Tieghem describes his species as 1 mm. high.

The present variety is considered by its author as such on account of its smaller size and much larger spores.

#### SUBFAM. 5. SYNCEPHALIDEÆ.

Vegetative hyphæ anastomosing; sporangia fasciculate, cylindrical, simple or branched; spores seriate; columella absent.

*Syncephalis*. The only British genus.

#### **Syncephalis.** Van Tiegh.

Mycelium soft, anastomosing; sporangiferous hyphæ erect, straight or curved, much thicker than the mycelium, simple, terminating in a subglobose vesicular swelling from which the sporangia radiate; sporangia cylindrical, simple or branched, gonidia in a single row; chlamydogonidia globose, on lateral mycelial branches. Zygosporoes globose, small.

*Syncephalis*, Van Tiegh. and Le Mon., Ann. Sci. Nat. ser. vi. vol. i. p. 372; Sacc. Syll. vii. p. 227.

A very remarkable genus; the aseptate sporangiferous hyphæ terminate in a swollen head, from which the numerous narrowly cylindrical sporangia radiate.

The general appearance is that of *Penicillium*, but in the latter the radiating chains of gonidia are naked or not enclosed in sporangia. The genus *Piptcephalis*, which has not yet been met with in Britain, resembles the present in the form and arrangement of the sporangia, but it is distinguished by the repeatedly forked sporangiophores.

*Syncephalis fasciculata*, Van Tiegh. (figs. 22, 23).

Sporangiferous hyphæ erect, fasciculate, colourless, inflated at the base, and becoming attenuated upwards, terminating in a spherico-depressed, warted vesicle; sporangia containing only few gonidia, cylindrical, simple or forked, springing from the warts on the apical vesicle; gonidia cylindrical, truncate at the ends, colourless,  $6.7 \times 3.3.5 \mu$ .

*Syncephalis fasciculata*, Van Tiegh. Ann. Sci. Nat. ser. vi. vol. i. p. 130, t. 3, figs. 120—122; Sacc. Syll. vii. n. 787.

Forming minute mould-like patches on damp substances or in water. Rare.

Sporangiferous hyphæ 300-400  $\mu$  high, 16-20  $\mu$  thick at the basal swollen portion, and tapering up to 4-6  $\mu$  at the apex.

## FAM. 2. PERONOSPORACEÆ.

Hyphæ usually branching; asexual reproduction by zoosporangia, containing zoogonidia that germinate at once, or by gonidia that germinate by developing a germ-tube; sexual reproduction by oogonia and antheridia.

*Analysis of the Genera.*

A. Gonidia catenulate, formed within the tissues of the host.

*Cystopus*. Gonidia and oospores producing zoospores.

B. Gonidia solitary, borne on gonidiophores that emerge from the matrix into the air.

*Phytophthora*. Gonidia producing zoogonidia, at first produced terminally on the gonidiophores, then apparently laterally also.

*Plasmopara*. Gonidiophores sparingly branched. Oospore with a thin, smooth wall.

§ Gonidiophores repeatedly dichotomously branched, terminal branchlets subulate, curved.

*Bremia*. Haustoria of mycelium branched; gonidia papillate at the apex, germ-tube emerging from the papilla.

*Peronospora*. Haustoria of mycelium not branched; gonidia not papillate, germ-tube issuing laterally.

**Cystopus, Lev.**

Gonidiophorous hyphæ short, simple, smooth, cylindrical or clavate, very obtuse, springing in fascicles from the mycelium, bearing a single row of concatenate gonidia at the apex; gonidia either all alike, colourless, giving origin to zoospores, or the terminal gonidium is furnished with a thicker, yellowish membrane, and germinates by the emission of a tube, or is sterile. The sori remain covered with the epidermis until the gonidia are mature, and then burst through. Oospores globose, episporium usually reticulated or warted.



*Cystopus*, Lév. Ann. Sci. Nat. ser. iii. vol. viii. p. 371 (1847); Cke. Hdbk. p. 324; Sacc. Syll. vii. p. 233.

The minute white or yellowish sori at first covered by the epidermis, and then, bursting through, with the crowded gonidiophores, bearing each a terminal chain of gonidia, characterize the present genus.

*Cystopus candidus*, Lév. (figs. 99, 100, 127, 128).

Sori white, erumpent, form variable, often broadly expanded and confluent, gonidia all similar, white, globose, 10-16  $\mu$  diameter; oospores subglobose, 35-45  $\mu$ , epispore yellowish brown, or sometimes dark brown, with coarse warts which sometimes pass into irregular, wavy ridges.

*Cystopus candidus*, Lév. Ann. Sci. Nat. ser. iii. vol. viii. p. 371; Cke. Hdbk. n. 1564, fig. 214; Sacc. Syll. vii. n. 792; Cke. Micr. Fung. pl. x. figs. 198—209 and 205—207.

On various cruciferous plants, especially shepherd's purse, *Capsella bursa-pastoris*; appearing on the stem, leaves, pedicels, fruit, &c., forming rather bullate or inflated white patches of variable extent, which produce distortion of the parts attacked. All the gonidia produce zoogonidia. Very common.

*Cystopus tragopogonis*, Schroet.

Sori irregularly globose or oblong, compressed, often concentrically arranged, white; terminal gonidium larger than the rest, depresso-globose, usually umbilicate below, wall thick, yellowish or colourless, sterile; remainder of gonidia shortly cylindrical, wall colourless, furnished with a trans-

verse, thickened, ring, 19-23  $\mu$  diameter, producing zoogonidia on germination; oospore spherical, epispore brown, with large, hollow, irregular warts, which are themselves minutely warted, 45-60  $\mu$ .

*Cystopus tragopogonis*, Schroet. Kr. Fl. Schles. Pilze, p. 234; Sacc. Syll. vii. n. 793.

*Cystopus cubicus*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 132, tab. 2; Cke. Hdbk. n. 1563; Cke. Micr. Fung. pl. x. ff. 201, 202, and 210.

*Uredo candida*,  $\beta$  *tragopogi*, Pers. Syn. Fung. p. 223.

On both surfaces of leaves of various composite plants, especially goat's-beard, *Tragopogon pratensis*; also on some plants belonging to the order *Convolvulaceæ*, as *Convolvulus* and *Ipomœa*. Not uncommon.

Bearing a superficial resemblance to *Cystopus candidus*, but readily distinguished by the cuboid gonidia.

#### Var. *spinulosus*.

With the general characters of *C. tragopogonis*, but eventually the gonidia become elongated, warts of oospore very prominent, often becoming spinulose.

*Cystopus spinulosus*, De Bary, Ann. Sci. Nat. ser. iv. vol. 20, p. 133; Cke. Hdbk. n. 1566; Sacc. Syll. vii. n. 794.

On leaves of various thistles. Local.

#### *Cystopus lepigoni*, De Bary.

Sori yellowish, usually in minute, scattered pustules; terminal gonidium of chain longer than the rest, thick-walled, globose, sterile, the remainder producing

zoogonidia on germination, globose or globoso-cylindrical, wall thin, colourless, 18-21  $\mu$ ; oospore globose, episporous brown, with numerous minute warts which sometimes become spinulose, 45-55  $\mu$  diameter.

*Cystopus lepigoni*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 132; Cke. Hdbk. n. 1565; Cke. Micr. Fung. p. 214; Sacc. Syll. vii. n. 796.

On leaves of various caryophyllaceous plants, as *Spergularia rubra*, *Arenaria media*, &c. Local. Distinguished from other species having a large apical gonidium by the very small, numerous warts on the episporous of the oospore.

### **Phytophthora**, De Bary.

Mycelium ramifying in the tissues of the host, haustoria scattered or absent; gonidiophores generally sparingly branched, gonidia at first terminal on the branchlets, then apparently lateral also, elliptical, apex papillate, producing zoogonidia on germination. Oospore globose, episporous smooth, rather thin, brown.

*Phytophthora*, De Bary, Journ. Bot. 1876, pp. 105—126, 149—154; Sacc. Syll. vii. p. 237.

*Peronospora* of various authors. The gonidia at first appear on the tips of the branches, but after the formation of a gonidium, the branch producing it continues to elongate in the direction of the original branch, and the first gonidium, that was a terminal product, is pushed on one side, and appears as a lateral development; this process is repeated two or three times by each branch.

*Phytophthora infestans*, De Bary (figs. 121—126).

Mycelium slender, haustoria very rare; gonidiophores slender, attenuated upwards, furnished above with a few slender, tapering, simple or rarely divided branches; branches with scattered, swollen portions corresponding to the points of origin of gonidia; gonidia elliptical, colourless, with a prominent papilla at the apex,  $25-30 \times 15-20 \mu$ ; sexual condition unknown.

*Phytophthora infestans*, De Bary, Journ. Agric. Soc. ser. ii. vol. xii. 1876; Sacc. Syll. vii. 802.

*Peronospora infestans*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 101; Cke. Hdbk. n. 1774; Cke. Micr. Fung. t. 14, f. 264.

On leaves of the potato, *Solanum tuberosum*. Very common.

Causing the well-known potato disease. The gonidiophores emerge from every above-ground part, but more especially from the under surface of the leaves, forming a white downy film. The mycelium is perennial in the tubers. Occurs also on other species of *Solanum*.

### **Plasmopara**, Schroet.

Mycelium thick, furnished with simple globose or ovate haustoria; gonidiophores erect, sparingly branched; gonidia generally papillate; oospores globose, epispore thin, smooth, brownish.

*Plasmopara*, Schroet. Krypt. Fl. Schles. Pilze, p. 236; Sacc. Syll. vii. p. 239.

*Peronospora* of various authors.

The species form white films on living leaves and other parts of plants, included under the popular

term *mildew*. Distinguished from *Phytophthora* by the absence of vesiculose swellings on the branches of the gonidiophore.

*Plasmopara entospora*, Schroet.

Gonidiophores in small tufts on the under-surface of the leaf, whitish, becoming brown, cylindrical, aseptate,  $140-160 \times 10-14 \mu$ , base slightly inflated, and furnished with a few slender mycelial branches, apex slightly inflated and giving origin to a few (8—12) slender sterigmata, slightly incrassated at the tips,  $10-12 \times 1-2 \mu$ , gonidia elliptical, papillate, very pale yellow,  $20-25 \times 12-14 \mu$ ; microgonidia elliptical, hyaline,  $5-6 \times 3.5-4 \mu$ ; oogonia globose, containing a single oospore with a thick membrane.

*Plasmopara entospora*, Schroet. Krypt. Fl. Schles. Pilze, p. 237; Sacc. Syll. vii. 805.

On under surface of leaves of *Erigeron Canadensis*, and on *Aster*. Rare.

*Plasmopara pygmæa*, Schroet.

Mycelium thick, variously constricted, haustoria minute, more or less piriform; gonidiophores slender, often in fascicles of 2—6, simple, or branched above, branches simple or once or twice dichotomous, tips surmounted by 2—4 short, cylindrico-conical branchlets, which are truncate after the gonidia fall away; gonidia elliptical, size variable,  $18-25 \times 15-20 \mu$ , apex broadly and obtusely papillate; oogonium globose,  $45-55 \mu$ , episporium thin, yellowish-brown, smooth or minutely rugulose, endospore thick.

*Plasmopara pygmæa*, Schroet. Krypt. Fl. Schles. p. 239; Sacc. Syll. vii. 807.

*Peronospora pygmaea*, Cke. Hdbk. n. 1776; Cke. Micr. Fung. t. 15, f. 267.

On leaves of various ranunculaceous plants, as *Anemone nemorosa*, and on other species of *Anemone*, *Aconitum*, *Hepatica*, *Isopyrum*, &c. Local.

Forming very minute whitish tufts, that become greyish-brown. The gonidiophores are often unbranched, and towards the apex furnished with 2—5 spicules bearing the gonidia.

*Plasmopara nivea*, Schroet.—(figs. 66-70).

Mycelium stout, often torulose or variously contorted, haustoria numerous, piriform; gonidiophores fasciculate, rather short,  $250-300 \times 8-10 \mu$ , tapering upwards, simple, or once or twice bi-, trifurcate, with 1-4 usually very short spreading branches, rarely elongated, these in turn are once or twice bi-, trifurcate at the apex, ultimate branchlets conico-subulate, spreading, straight, rarely slightly flexuous and bearing the broadly elliptical gonidia, which have a very thin, hyaline membrane, apical papilla very indistinct, protoplasm granular,  $21-25 \times 15-18 \mu$ ; oogonia irregularly spherical, hyaline or pale yellow; oospore globose, large, yellowish-brown, smooth or minutely rugulose.

*Plasmopara nivea*, Schroet. Krypt. Fl. Schles. p. 237; Sacc. Syll. vii. 803.

*Peronospora nivea*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 105; Cke. Hdbk. n. 1775; Unger, Bot. Ztg. 1847, p. 314 (in part).

On living leaves of various umbelliferous plants, as *Ægopodium podagraria*, *Anthriscus sylvestris*, *Angelica sylvestris*, *Pimpinella magna*, *P. saxifraga*, *Sium*

*latifolium*, *Pastinaca sativa*, *Petroselinum sativum*, *Peucedanum palustre*, *Daucus carota*, *Conium maculatum*, *Meum athamanticum*; also on species belonging to the following genera, *Helleosciadium*, *Laserpitium*, and *Selinum*. Not uncommon.

Sometimes sufficiently abundant to form a delicate white bloom on the leaves. The roots of plants infested with the *Peronospora* are often diseased, owing to the presence of permanent mycelium, as in the case of *Phytophthora infestans*.

*Plasmopara densa*, Schroet.

Forming small, scattered, or confluent tufts, white, then yellowish; mycelium with vesicular haustoria; gonidiophores 160-180  $\mu$  high, towards the apex divided into 2-3 main branches, each with 1-3 horizontal branches springing from the apical portion, and these again bearing 1-3 branchlets; gonidia broadly elliptical or subglobose, 12-16 or 12-15  $\times$  10-12  $\mu$ , minutely and obtusely apiculate at the apex; oospores globose, epispore thin, pale yellow.

*Plasmopara densa*, Schroet. Kr. Fl. Schles. Pilze, p. 239; Sacc. Syll. vii. 1, n. 814.

Parasitic on the living leaves of *Euphrasia officinalis* and *Bartsia odontites*. Rare.

**Bremia**, Regel.

Mycelium furnished with vesicular or clavate simple haustoria; gonidiophores several times dichotomously divided, branchlets umbellate, tips inflated in a turbinate or subglobose manner, the swellings give origin to a few (2-8) conical, short sterigmata,

carrying the subspherical gonidia. Oospores minute, globose, episporic rugulose, yellow-brown.

*Bremia*, Regel, in Bot. Ztg. 1843, p. 665; Sacc. Syll. vii. p. 243.

*Peronospora* of various authors. Characterized by the much branched gonidiophores, subglobose, papillate gonidia, and small oospores.

*Bremia lactucæ*, Regel (figs. 64—65).

Mycelium stout, often variously twisted, haustoria subclavate, simple; gonidiophores 2—6 times dichotomously, or sometimes trichotomously, branched, stem and primary branches inflated above, the ultimate branchlets inflated at the tips into subclavate or subglobose vesicles, bearing 2—8 minute, conical spicules, each carrying a subglobose gonidium, with a broad, depressed, apical papilla, 16-23  $\mu$  diameter; oospores globose, yellow-brown, pellucid, rugulose, 25-35  $\mu$ .

*Bremia lactucæ*, Regel, Bot. Ztg. 1843, p. 665, t. 3, f. B.; Sacc. Syll. vii. p. 243.

*Peronospora gangliiformis*, Cke. Hdbk. n. 1777; Cke. Micr. Fung. t. 14, f. 265.

On living leaves of various composite plants, as illustrated by the following genera,—*Lactuca*, *Senecio*, *Helichrysum*, *Cirsium*, *Centaurea*, *Lapsana*, *Leontodon*, *Tragopogon*, *Hypochaeris*, *Mulgedium*, *Sonchus*, *Crepis*, and *Hieracium*. It is also common on garden lettuce *Lactuca scariola*, var. *sativa*.

### **Peronospora, Corda.**

Mycelium generally furnished with filiform branched haustoria; gonidiophores solitary or fasci-



culate, emerging through the stomata, cylindrical, generally many times dichotomously divided above, terminal branchlets often acuto-incurved and bearing the elliptical gonidia, which are not furnished with an apical papilla, and germinate by the protrusion of a lateral germ-tube.

*Peronospora*, Corda, Icon. i. p. 20; Sacc. Syll. vii. p. 244.

*Peronospora*, Cke. Hdbk. p. 592 (in part).

Forming thin "mildew" on the living leaves of plants; known amongst its allies by the filiform branched haustoria, and absence of a papilla at the apex of the gonidium.

*A. Calothecæ*, De Bary. Oospore globose, epispore warted, or with ridges that often anastomose and form a reticulation. Mycelium generally bearing filiform branched haustoria.

*Peronospora calotheca*, De Bary.

Gonidiophores slender, 7—9 times dichotomously divided above, primary branches suberect, remainder spreading on every side, ultimate branchlets very slender, short, straight or slightly curved; gonidia elliptical,  $25-30 \times 14-17 \mu$ , rounded and obtuse at both ends, very pale lilac; oospores globose, epispore stout, bay, with thin ridges united to form a minute reticulation.

*Peronospora calotheca*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 111 (1863); Sacc. Syll. vii. 817.

*Peronospora galii*, Fuckel, F. Rhen. n. 28.

*Peronospora sherardiae*, Fuckel.

On leaves of several rubiaceous plants, as *Galium verum*, *G. aparine*, *G. palustris*; *Asperula odorata*; *Sherardia arvensis*, &c. Not common.

*Peronospora myosotidis*, De Bary.

Gonidiophores slender, elongated, generally emerging through the stomata of the leaf in pairs, uniformly 6—9 times dichotomously divided, all the branches spreading, terminal branchlets very slender; gonidia elliptical, very obtuse at both ends,  $20-23 \times 13-18 \mu$ , wall thin, with a faint tinge of lilac; oospores globose,  $25-30 \mu$ , epispore stout, clear yellow-brown, with thick ridges combined to form a regular, large-meshed reticulation.

*Peronospora myosotidis*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 112; Sacc. Syll. vii. 818.

On various boraginaceous plants, as *Myosotis arvensis*, *M. hispida*; *Symphytum officinalis*, *S. tuberosum*; *Lithospermum arvense*, &c. Not common.

*Peronospora viciæ*, De Bary.

Gonidiophores forming dense, effused, whitish, then pale pinkish-grey tufts, equally, rarely irregularly 6—8 times dichotomously branched, branches squarrose, the ultimate branchlets subulate, short; gonidia elliptical, apex rounded, base blunt or rather acute, membrane thin, pale dingy violet,  $25-28 \times 15-18 \mu$ ; oospores globose, pale yellow-brown, with ridges united to form a regular, wide-meshed reticulation.

*Peronospora viciæ*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 112; Sacc. Syll. vii. 819; Cke. Hdbk. n. 1779; Cke. Micr. Fung. t. 15, f. 266; t. 10, f. 212.

*Botrytis viciæ*, Berk., Journ. Hort. Soc. i. 31.

On leaves of leguminous plants, *Vicia faba* (Berkeley's type specimen is on this species), *V. sepium*, *V. hirsuta*, *V. tetrasperma*, *V. cracca*, *V. sativa*; *Pisum sativum*, *Lathyrus pratensis*, *Orobus tuberosa*, *Melilotus officinalis*, &c. Common. Often forming a dense felt on the under surface of the leaves.

*Peronospora arenariæ*, Tul.

Gonidiophores forming delicate, effused, white tufts, often emerging singly from the stomata, slender, 6—7 times equally, rarely irregularly, dichotomously divided; branches spreading, terminal branchlets very slender, subulate, straight; gonidia elliptical, very obtuse at both ends,  $20-25 \times 14-16 \mu$ , very slightly tinged lilac; oospores globose, clear brown, with stout hemispherical warts that sometimes have a tendency to become elongated,  $24-30 \mu$  diameter.

*Peronospora arenariæ*, Tulasne, Compt. Rend. Acad. Sc. tab. xxxviii.; Cke. Hdbk. n. 1780; Cke. Micr. Fung. t. 7, f. 268, t. 10, f. 211; Sacc. Syll. vii. 823.

*Botrytis arenariæ*, Berk. Journ. Hort. Soc. i. p. 31, tab. 4.

On leaves of various caryophyllaceous plants. *Arenaria serpyllifolia*; Berkeley's type specimen is on *A. trinervis*; *Stellaria media*. Not uncommon.

B. *Leiothecæ*, Schroet. (= *Parasiticæ* and *Effusæ* of De Bary). Oospores subglobose, epispore usually smooth, sometimes slightly regulose, but not distinctly warted nor reticulated. Mycelium often as in *Calothecæ*.

*Peronospora parasitica*, De Bary (figs. 45, 46, 129).

Mycelium thick, very much branched, branches thick, obtuse or subclavate, curved, often entering into and filling up the cells of the host, haustoria numerous, branched; gonidiophores thick, soft, flexuous, equal or unequal, 5—8 times dichotomously, rarely trichotomously divided, branches repeatedly bi-trichotomous, the branches continue to become more slender from the first order, ultimate branchlets subulate, more or less arcuate; gonidia broadly elliptical, colourless, apex very obtuse,  $20\text{--}25 \times 16\text{--}20 \mu$ ; oogonia angularly globose, membrane very thick, stratified colourless or yellowish, oospores globose, smooth or slightly rugulose, yellowish or brownish,  $25\text{--}45 \mu$  diameter.

*Peronospora parasitica*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 110; Sacc. Syll. vii. 830; Cke. Hdbk. n. 1778; Cke. Micr. Fung. t. 14, f. 265.

On leaves and inflorescence of various cruciferous plants, often in company with *Cystopus candidus*. Has been met with on various species of the following genera—*Capsella*, *Nasturtium*, *Barbarea*, *Turritis*, *Arabis*, *Cardamine*, *Dentaria*, *Hesperis*, *Sisymbrium*, *Erysimum*, *Cheiranthus*, *Matthiola*, *Brassica*, *Sinapis*, *Alyssum*, *Erfophila*, *Camelina*, *Thlaspi*, *Lepidium*, *Diplotaxis*, *Bunias*, *Raphanus*, *Neslia*. Not uncommon.

*Peronospora ficariæ*, Tul.

Forming broadly effused, dirty white, then greyish-lilac tufts; gonidiophores short, 5—7 times equally or unequally dichotomously divided, ultimate or penulti-

mate branches often arcuate, ultimate branchlets often elongato-subulate; gonidia broadly elliptical, pale dirty lilac,  $20-25 \times 15-18 \mu$ ; oospores with a thickish, pale yellowish-brown, smooth membrane,  $22-32 \mu$  diameter; oogonia subglobose, brown, almost smooth,  $35 \mu$  diameter.

*Peronospora ficariae*, Tulasne, Compt. Rend. 26 Jan. 1854; Sacc. Syll. vii. 835.

On under surface of living leaves of *Ranunculus ficaria*, *R. acris*, *R. flammula*, *R. auricomus*, *R. bulbosus*. Not common.

Often covering the entire plant and producing fruit everywhere, except on the roots and flowers.

*Peronospora arborescens*, De Bary.

Gonidiophores slender, erect, towards the top 7—10 times divided in a dichotomous manner, branches spreading, more or less flexuous, becoming thinner from the first order, ultimate branchlets very slender, short, subulate, more or less curved; gonidia subglobose,  $15-24 \times 15-20$ , very pale lilac; oospores globose, epispore brown, minutely strialulate,  $25-35 \mu$  diameter.

*Peronospora arborescens*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 119; Cke. Hdbk. n. 1785; Cke. Micr. Fung. p. 217; Sacc. Syll. vii. n. 836.

*Botrytis arborescens*, Berk. Journ. Hort. Soc. 1, p. 31, t. 4, f. 24.

On the under surface of leaves of plants belonging to the genus *Papaver*, as *P. rhoeas*, *P. dubium*, *P. somniferum*, *P. agremoides*. Not uncommon.

Often almost entirely covering the under surface of the leaves with a thin cottony felt.

*Peronospora affinis*, Rossm.

Gonidiophores stout, regularly 5—7 times dichotomously divided, branches spreading, ultimate branchlets short, subulate, straight or curved towards the base; gonidia elliptical,  $22-26 \times 15-18$ , obtuse, pale dingy-lilac; oospores globose, epispore smooth, brown.

*Peronospora affinis*, Rossm. in Rab. Herb. Myc. ed. ii. n. 189; De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 118; Sacc. Syll. vii. n. 837.

On leaves of *Fumaria officinalis*. Rare.

*Peronospora violæ*, De Bary.

Forming felt-like, effused, pale greyish-lilac patches; gonidiophores fasciculate, short, 2—7 times dichotomously divided, ultimate branchlets short, subulate, deflexed; gonidia elliptical, shortly apiculate, pale lilac,  $20-24 \times 14-18 \mu$ .

*Peronospora violæ*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 125; Sacc. Syll. vii. n. 838.

On living leaves of *Viola tricolor* and *V. Riviniana*. Rare.

Recedes from the genus *Peronospora* in having the gonidia apiculate, but typical in other respects.

*Peronospora trifoliorum*, De Bary.

Forming effused greyish patches; gonidiophores equally or unequally 6—7 times dichotomously or rarely trichotomously divided, ultimate branchlets subulate, acute, slightly curved; gonidia ellipsoid, very obtuse, pale dirty lilac,  $18-27 \times 15-20 \mu$ ; oospores globose, brown, smooth,  $25-38 \mu$  diameter.

*Peronospora trifoliorum*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 117, 1863; Sacc. Syll. vii. no.

841; Cke. Hdbk. n. 1783; Cke. Micr. Fung. p. 216.

On living leaves of leguminous plants belonging to the following genera:—*Ononis*, *Medicago*, *Melilotus*, *Trifolium*, *Lotus*, *Coronilla*, *Astragalus*, *Orobus*. Common. Usually covering the entire under surface of the leaves with a very delicate greyish film.

*Peronospora violacea*, Berk.

Forming minute, scattered, pale lilac tufts; mycelium with saccate haustoria; gonidiophores very short, 5—7 times dichotomously divided, primary branches few, erect, terminal branchlets short, erect; gonidia elliptical, lilac,  $30-40 \times 16-20 \mu$ ; oospores globose, epispore brown, irregularly plicate, thick ( $5-8 \mu$ ),  $20-26 \mu$  diameter.

*Peronospora violacea*, Berk. Outl. p. 349; Cke. Hdbk. n. 349; Cke. Micr. Fung. p. 217; Sacc. Syll. vii. 846.

On petals of *Scabiosa arvensis*. Not uncommon.

The vesicular haustoria are unusual in the genus *Peronospora*.

Possibly the above species is identical with a fungus described by Léveillé (Ann. Sci. Nat. 1846, p. 298) as "*Botrytis violacea*; hyphæ erect, continuously dichotomously branched; gonidia ovate, glabrous, violet."

On flowers of *Pyrethrum arvense*, and on living leaves of *Lathyrus palustris*. Found in France.

*Peronospora grisea*, De Bary.

Forming dense, felt-like, violet-grey tufts on the under surface of leaves; gonidiophores fasciculate,

thick, greyish-violet, 5-7 times regularly dichotomously divided; branches attenuated upwards, the primary ones ascending, the remainder patent, flexuous, ultimate branchlets generally unequal, slightly curved; gonidia elliptical, very obtuse, pale dirty lilac,  $25-30 \times 15-22 \mu$ ; oospores clear brown, wall thick, smooth,  $30-40 \mu$  diameter.

*Peronospora grisea*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 119, t. 13, f. 12; Cke. Hdbk. n. 1784; Cke. Micr. Fung. t. 10, f. 213; Sacc. Syll. vii. 852.

*Botrytis grisea*, Unger. Bot. Ztg. 1874, p. 315.

On under surface of leaves of scrophulariaceous plants,—*Veronica beccabunga*, *V. serpyllifolia*, *V. scutellata*, *V. arvensis*, *V. verna*, *V. triphylla*, *V. hederæfolia*, *V. anagallis*. Not uncommon.

*Peronospora lamii*, De Bary.

Forming dense, effused, greyish-lilac patches, gonidiophores short, 5—7, generally 6 times dichotomously divided, branches tapering upwards, spreading, more or less curved, ultimate branchlets generally elongated, subulate; gonidia broadly elliptical, with a short persistent pedicel, pale dingy lilac,  $17-22 \times 15-20$  oospores small, brown.

*Peronospora lamii*, De Bary, in Rab. Herb. Myc. ed. ii. n. 325; Sacc. Syll. vii. 853.

On under surface of leaves of labiate plants, as *Lamium album*, *L. rubrum*, *L. amplexicaule*, *L. maculatum*; *Salvia pratensis*, *Stachys palāstris*. Not common.

Often forming broadly effused felt-like patches on under surface of leaves.



*Peronospora effusa*, Rabenh.

Forming effused greyish spots; gonidiophores fasciculate, emerging through the stomata, short, thick, 2—7 times dichotomously divided above, ultimate branchlets thick, shortly subulate, curved downwards; gonidia elliptical, distinctly pedicellate, pale dingy lilac,  $25-35 \times 15-24 \mu$ ; oospore globose, episporium clear brown, irregularly wrinkled,  $25-38 \mu$  diameter.

*Peronospora effusa*, Herb. Myc. Fung. no. 1880; Sacc. Syll. vii. n. 854; Cke. Hdbk. n. 1781; Cke. Micr. Fung. t. 10, figs. 214, 215.

On living leaves of plants belonging to the orders *Chenopodiaceæ*, *Polygonaceæ*, and *Violaceæ*, as *Chenopodium album*, *C. muralis*, *C. glaucum*, *C. polyspermum*, *C. hybridum*, *C. Bonus-Henricus*, *Spinacia oleracea*, *Atriplex patula*, *A. nitens*, *A. hastata*, *A. rosea*, *Polygonum convolvulus*.

The following varieties have not yet been met with in Britain.

Var. *a minor*, branches slenderer than in type, erecto-patent, ultimate branchlets subulate, subsquarrose, straight or slightly curved, not deflexed; gonidia globoso-elliptical, pedicel scarcely conspicuous. On *Atriplex*.

Var. *β violæ* on leaves of *Viola tricolor*, var. *arvensis*.

Var. *γ polygoni*, distinguished from the type form by the whitish colour of the small tufts.

Forming usually broadly effused patches on the under surface of leaves. Common on cultivated spinach.

*Peronospora urticæ*, De Bary.

Gonidiophores small, loosely 4-6 times dichoto-

mously divided, branches flexuous, ultimate branchlets subulate, curved and often deflexed; gonidia broadly elliptical or subglobose, distinctly pedicellate, apex very obtuse,  $20-28 \times 17-21 \mu$ , pale dingy lilac; oospores globose, brown, smooth,  $21-25 \mu$  diameter.

*Peronospora urticæ*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 116; Sacc. Syll. vii. n. 856; Cke. Hdbk. n. 1782; Cke. Micr. Fung. p. 216.

On the under surface of leaves of common nettle, *Urtica dioica* and *U. urens*. Not uncommon.

Forming small lilac-grey patches. Cooke says that the gonidia have the apex papillæform, but very obtuse

*Peronospora Schleideni*, Unger.

Forming greyish-lilac tufts; gonidiophores large, erect, aseptate,  $250-400 \mu$  high, branched alternately or in a dichotomous manner, ultimate and penultimate branches strongly arched; gonidia obovate, apex obtuse or subacute, pale dingy violet,  $45-55 \times 22-25 \mu$ ; oospores broadly elliptical or globose, epispore thin, smooth.

*Peronospora Schleideni*, Unger, Bot. Ztg. 1847, p. 315; Sacc. Syll. vii. n. 857.

*Peronospora Schleideniana*, Cke. Hdbk. n. 1787; Cke. Micr. Fung. t. 13, f. 263.

*Botrytis destructor*, Berk. Ann. Nat. Hist. vol. vi. p. 436, t. 13, f. 23.

On leaves of various species of *Allium*. Not uncommon.

Forming broadly effused patches which sometimes entirely cover the leaves; very destructive during some seasons to the cultivated onion.

Characterized by the obovate gonidia.

*Peronospora candida*, Fekl.

Forming broadly effused, white patches, gonidiophores thin, erect, simple for some distance above, 6—10 times dichotomously divided, ultimate branchlets slender, spreading, often slightly curved; gonidia broadly elliptical, very obtuse,  $15-18 \times 10-13 \mu$ ; oospores globose, rugulose, bright brown,  $30-36 \mu$  diameter.

*Peronospora candida*, Fuckel, Fung. Rhen. n. 38; Cke. Hdbk. n. 1786; Cke. Micr. Fung. ed. 2, p. 225; Sacc. Syll. vii. n. 860.

On living primrose leaves, frequently covering a considerable portion, or the whole of the under surface, with a white, minutely-velvety layer. Local. This species has occurred in Germany on the leaves of *Anagallis arvensis*, var. *cærulea*.

*Peronospora hyoscyami*, De Bary.

Gonidiophores stout, tall, 5—8 times dichotomously divided, branches spreading, becoming thinner, straight or curved, ultimate branchlets spreading at very obtuse angles, short, conico-subulate, straight; gonidia elliptical, very obtuse, pale lilac,  $13-24 \times 13-18 \mu$ .

*Peronospora hyoscyami*, De Bary, Ann. Sci. Nat. ser. iv. vol. xx. p. 123; Sacc. Syll. vii. n. 877.

*Peronospora effusa*, var. *hyoscyami*, Rab. Fung. Eur. n. 291.

On living leaves of *Hyoscyamus niger*. Rare.

Forming scarcely conspicuous, greyish-brown,

tomentose patches on the under surface of the leaves.

*Peronospora sordida*, Berk.

Forming broadly effused dingy patches; gonidiophores tall, lower unbranched portion elongated, equal, dividing irregularly into 3—6 main branches, which are 2—4 times irregularly forked, often more or less curved downwards, bifurcate at the tips, ultimate branchlets short, conico-subulate, often curved and deflexed; gonidia broadly elliptical, obtuse, with a very faint tinge of lilac, or colourless,  $20-28 \times 15-20 \mu$ .

*Peronospora sordida*, Berk. Ann. Nat. Hist. ser. iii. vol. vii. p. 449, n. 953; Cke. Hdbk. n. 1789; Cke. Micr. Fung. p. 217; Sacc. Syll. vii. n. 881.

On under surface of leaves of *Scrophularia aquatica*, *S. nodosa*, *S. altaica*, *Verbascum blattaria*, *V. thapsus*, *V. thapsiforme*, *V. nigrum*, *V. virgatum*, *Digitalis purpurea*. Not uncommon.

The gonidia are described as obovate and apiculate, but I have not seen this in the type specimens or any other examined, but always as described above.

*Peronospora sparsa*, Berk.

Gonidiophores scattered, simple for some distance from the base, divided above into 3—5 main, suberect branches, which are 2—4 times irregularly forked, and sometimes slightly curved and deflexed, ultimate branchlets generally curved, conico-acuminate; gonidia broadly elliptical, very obtuse,  $17-20 \times 14-16 \mu$ .

*Peronospora sparsa*, Berk. Gard. Chron. 1862, p. 308, with fig.; Cke. Hdbk. n. 1790; Sac. Syll. vii. n. 884.

On under surface of living rose leaves. Rare.

Gonidiophores scattered or aggregated and forming an almost imperceptible grey film. The type specimen in Berkeley's herbarium is on the leaves of some large cultivated rose.

### FAM. 3. SAPROLEGNACEÆ.

Asexual mode of reproduction by zoogonidia that are generally biciliate; the hyphæ becoming partly or entirely transformed into zoosporangia; sexual mode by oogonia and antheridia.

#### *Analysis of the Genera.*

A. Zoosporangia formed from the terminal portions of the hyphæ. Antherozoids not formed from protoplasm of antheridia.

§ Filaments more or less constricted at intervals.

*Leptomitus*. Zoogonidia biciliate.

§§ Filaments not constricted.

\* Zoogonidia always destitute of a membrane.

*Saprolegnia*. Zoogonidia evolved within the zoosporangia; oogonia generally polysporous.

*Pythium*. Zoogonidia evolved after escaping from the zoosporangia; oogonia monosporous.

\*\* Zoogonidia at first with a distinct membrane from which they escape before leaving the zoosporangia.

*Dityuchus*. Oogonia not perforated.

*Diplanes*. Oogonia perforated.

\*\*\* Zoogonidia naked while in the zoosporangia, becoming invested with a membrane after their escape.

*Achlya*. Zoogonidia arranged without order in the zoosporangia ; oogonia polysporous.

*Aphanomyces*. Zoogonidia arranged in a uniseriate manner in cylindrical zoosporangia ; oogonia uni-, bisporous.

B. Zoosporangia arranged in a seriate manner ; antherozoids formed from protoplasm of antheridia.

*Monoblepharis*. Zoogonidia uniciliate.

### Leptomitius, Agardh.

Hyphæ constricted at regular intervals, sparingly branched ; zoosporangia formed from the terminal portions of the branches, one or several superposed ; zoogonidia maturing within the zoosporangium and not escaping until after germination.

*Leptomitius*, Agardh, Syst. Alg. p. 50 ; Sacc. Syll. vii. p. 265.

Closely allied to the genus *Saprolegnia*, and distinguished chiefly by the hyphæ being constricted at regular intervals.

*Rhipidium*, a genus not known in Britain, agrees with *Leptomitius* in the constricted filaments, but is distinguished by the flabellately arranged branches.

### *Leptomitius lacteus*, Ag. u/

Forming tassel-like waving tufts, attached at the base, dirty white and slimy ; filaments up to 5 cm. long and 6-12  $\mu$  thick, constricted at intervals, dichotomously branched, flaccid ; zoosporangia ter-

minal on the filaments or axillary; zoogonidia ovate,  $2\ \mu$  long, furnished with two cilia about  $12\ \mu$  long.

*Leptomitius lacteus*, Ag. Syst. p. 50; Sacc. Syll. vii. 888.

*Saprolegnia lactea*, Pringsh. Jahrb. vol. ii. t. xxiii. f. 10, and t. xxv. figs. 1—6.

In ditches and rivers, attached to wood, aquatic plants, &c. Not uncommon.

*Leptomitius brachynema*, Hildebr. (fig. 28).

Filaments constricted at intervals, short, sparingly branched, forming small flowing tufts; zoosporangia globose, generally containing six zoogonidia, terminal and solitary or aggregated,  $28\text{--}35\ \mu$  diameter; oogonia irregularly globose, adnate with the wall of the globose colourless oospore.

*Leptomitius brachynema*, Hildebrand, in Pringsh. Jahrbuch, vi. p. 261, t. xvi. figs. 12—23; Sacc. Syll. vii. 889.

Forming short, dirty white, flowing tufts, attached to submerged bodies in stagnant water. Rare.

Numerous forms considered by Kutzni<sup>g</sup> as algæ, and referred to by Saccardo as doubtful species of the present genus, have occurred in various chemical solutions, such as hydrate of ammonia, phosphoric acid, &c.; also in various other solutions.

### **Saprolegnia, Nees.**

Filaments not constricted, branched; zoosporangia clavate or cylindrico-clavate, after the zoogonidia escape the transverse septum at the base of the zoosporangium grows up as a second zoosporangium enclosed within the first empty one; zoogonidia com-

pletely evolved in the zoosporangium and escaping in the swarming state; oogonia containing many, rarely only one oospore; antheridia small, clavate or ovate, produced at the tips of special, slender branchlets.

*Saprolegnia*, Nees, Nov. Act. Leop. xi. 2, p. 513; Sacc. Syll. vii. p. 268.

Remarkable for the manner in which the zoosporangia appear within each other, the walls of the older ones being persistent and remaining as a sheath round the younger ones.

A. *Species monœcious.*

\* *Oogonia polysporous.*

*Saprolegnia androgynia*, Archer.

Monœcious; oogonia barrel-shaped or elliptical, generally in an uninterrupted terminal series, rarely interstitial; antheridial branches springing from the walls of the oogonia and fertilizing the oospheres of the oogonium immediately above the oogonium from which they originate, oospheres of lowest oogonium of the series fertilized by antheridia springing from the stem; oospores numerous in each oogonium, globose, 30-35  $\mu$  diameter.

*Saprolegnia androgynia*, Archer, Quart. Journ. Micr. Sci. vol. vii. new ser. p. 123, pl. vi. f. 1; Sacc. Syll. vii. n. 912.

"In one instance, in the mass made by the plant, three seeming sporangia (zoosporangia), evacuated by zoospores, one *within* the other, each showing a terminal opening, were observed . . . the whole plant large and coarse as compared with other described forms in this family" (Archer).



*Saprolegnia monoica*, Pringsheim. (fig. 38).

Oogonia with a terminal or lateral perforation, oospores hyaline, globose,  $20\ \mu$  diameter; antheridia formed at the tips of lateral branches.

*Saprolegnia monoica*, Pringsh. Jahrb. Band i. p. 292, t. xix. and xx.; Sacc. Syll. vii. n. 911; Archer, Proc. Dubl. Micr. Club, i. 17.

On flies, spiders, larvæ, &c., under water. Not common.

#### B. *Species dioecious.*

*Salprolegnia ferox*, Nees.

Main stem without lateral branches; oogonia perforated; oospores numerous, globose,  $30\ \mu$  diameter; antheridia ovate, produced on the tips of special filaments.

*Salprolegnia ferox*, Nees, in Kutz. Phyc. Gen. p. 256; Sacc. Syll. vii. n. 916; Cke. Hdbk. p. 639, figs. 308, 309.

*Saprolegnia dioica*, Schroet.

*Achlya prolifera*, Pringsh. Jahrb. Band ii.

On dead flies, fish, newts, &c., in water. Causing the well-known and destructive salmon disease. Common.

*Sporendium muscæ*, Fries., or *Empusa muscæ*, Cohn, was at one time considered to be an imperfect aerial condition of the present species, but it is now known that the two are not in any way related.

#### Pythium, Pringsheim.

Mycelium simple or branched, aseptate or with an occasional septum; walls of zoosporangia usually very thin and evanescent, zoogonidia always naked, be-

coming differentiated after leaving the zoosporangia; in some species large spherical gonidia are formed interstitially and terminal on the branchlets in immense numbers; oogonia monosporous; wall of mature oospore smooth or variously ornamented with raised bands.

*Pythium*, Pringsh. Jahrb. i. p. 288; Sacc. Syll. vii. p. 270.

Closely allied to the genus *Saprolegnia*, in fact the only difference between the two depends on the zoogonidia being fully evolved in the zoosporangium in *Saprolegnia*, whereas in *Pythium* the contents of the zoosporangia escape before the cilia of the zoogonidia are formed. The biological section of mycologists consider that the various slight modifications presented during the differentiation of the zoogonidia are of generic importance in the present group; time will, perhaps, prove whether this idea is correct.

*Pythium De-Baryanum*, Hesse. (figs. 39—42).

Mycelium branched, aseptate or with only an occasional septum; gonidia spherical, thin walled, terminating short lateral branches, or interstitial, 20-30  $\mu$  diameter; zoosporangia globose or broadly elliptical, sometimes shortly papillate, terminal or intercalary; oogonia globose, membrane not perforated; oospores globose, exospore thick, smooth, 25-35  $\mu$  diameter; antheridia clavate, on very short branches produced immediately below the oogonium, or on distinct branches.

*Pythium De-Baryanum*, Hesse, ein Endophytischer Schmarotzer, p. 34; Sacc. Syll. vii. n. 924; Ward,

Quart. Journ. Microscop. Sci. vol. 23 (1883), p. 487, pl. 24, ff. 1—10.

*Pythium equiseti*, Sadeb. in Sitz. d. Bot. Ver. der Prov. Brandenb. 1874, p. 166.

*Pythium vexans*, De Bary, Bot. Zgt. 1881, p. 537, t. v. ff. 3—7.

Parasitic or saprophytic in various plants, frequent in cress seedlings grown in damp, shady places. Common.

*Pythium proliferum*, De Bary.

Mycelium often profusely branched; zoosporangia elliptical or lemon-shaped, beaked, wall thick, zoogonidia reniform, biciliate, escaping through the diffuent apex of the beak, a second zoosporangium usually originates from the base and within the first empty one; oospores spherical, epispore smooth, 28–35  $\mu$  diameter; antheridia short, clavate, curved.

*Pythium proliferum*, De Bary, Pringsh. Jahrb. ii. p. 182, t. xxi. figs. 28—37; Sacc. Syll. vii. n. 926; Ward, Quart. Journ. Micros. Sci. vol. 23 (1883), p. 497, pl. 24 and 25, figs. 11—21.

On putrid insects and plants in stagnant water. Uncommon.

Not a good *Pythium*, departing from typical forms in the thicker wall of the zoosporangia, and in the proliferous habit, or development of one zoosporangium within another, as in *Saprolegnia*.

*Pythium cystosiphon*, Lindstedt.

Mycelium entophytic, aseptate or with an occasional septum, slender, 4–5  $\mu$  thick, penetrating the cells of the host; zoosporangia on short branches, formed

within the cells of the host, spherical or oblong, 30-35  $\mu$ ; zoogonidia subreniform, with a cilium at each end; oogonia globose, terminal or intercalary, oospore globose, epispore thick, with ridges forming a vague reticulation, 40-45  $\mu$  diameter; antheridia terminal on branches developed near the oogonia, which are perforated by a short beak.

*Pythium cystosiphon*, Lindstedt, Syn. Saproleg. p. 50; Sacc. Syll. vii. n. 927.

*Cystosiphon pythioides*, Roze et Corun, Ann. Sci. Nat. ser. v. vol. xi. p. 72, t. iii. figs. 1—22.

In living fronds of *Wolffia Michellii* (= *Lemna arrhiza*, L.) Rare.

*Pythium megalacanthum*, De Bary.

Mycelium branched, aseptate, branches tapering; zoosporangia spherical, elliptical, obovate, or irregular in outline, usually with several elongated beaks; zoogonidia subglobose, biciliate, 18-20  $\mu$  diameter; oogonia terminal or intercalary, 38-45  $\mu$  diameter, wall thick, with numerous stout, conical spines, 8-10  $\mu$  long; oospores globose, 25-30  $\mu$  diameter, smooth.

*Pythium megalacanthum*, De Bary, in Schroet. Kr. Fl. Schles. Pilze, p. 232.

In semiputrid vegetable remains in water. Rare.

Distinguished by the many beaked zoosporangia and the coarsely spinulose oogonia.

### **Dictyuchus**, Lietgeb.

Zoospores of two forms, escaping from their proper membranes before leaving the zoosporangia, the empty membranes remaining in the zoosporangia and

presenting a reticulated appearance; oogonia one or many spored, not perforated.

*Dictyuchus*, Lietg. in Pringsh. Jahrb. vii. p. 357; Sacc. Syll. vii. p. 273.

Closely resembling *Pythium*, the generic difference depending almost entirely on the thin membranes originally clothing the zoogonidia remaining in an empty condition in the zoosporangia, and giving to the latter a cellular appearance.

*Dictyuchus monosporus*, Lietg. (figs. 102—104).

Diœcious; hyphæ aseptate, branched; oogonia terminal on the branchlets, spherical, not perforated, 25-30  $\mu$  diameter, containing one globose, hyaline oospore; antheridia vermiform, branched, clasping, but not perforating, the oogonia; zoosporangia elongato-clavate, containing numerous spherical, biciliate zoogonidia, which emerge in the active condition, leaving their exceedingly delicate membranes in the form of a tissue or network in the zoosporangia.

*Dictyuchus monosporus*, Lietg. in Pringsh. Jahrb. vii. p. 371, pl. xxii., xxiii.; Sacc. Syll. vii. n. 936.

In rotting bulbs of tulips and hyacinths in water. Rare.

### **Diplanes, Lietg.**

Zoosporangia delicate, perforated, zoogonidia biciliate, at first enclosed in a delicate membrane, from which they escape before leaving the zoosporangium; oogonia perforated, polysporous.

*Diplanes*, Lietg. in Pringsh. Jahrb. vii. p. 374; Sacc. Syll. vii. p. 274.

Very near to the genus *Saprolegnia*, differing in the

zoogonidia being at first surrounded by a delicate membrane.

*Diplanes saprolegnioides*, Lietg. (figs. 91—93.)

Mycelium aseptate, slightly branched; oogonia terminal on the branchlets, perforated, 35-40  $\mu$  diameter, containing many spherical oospores; antheridia irregularly clavate, terminating lateral branches originating near the oogonia; zoosporangia terminal, cylindrical, furnished with one or two papillæ that become perforated for the escape of the subreniform, biciliate zoogonidia.

*Diplanes saprolegnioides*, Lietg. in Pringsheim's Jahrb. Bd. vii. p. 374, tab. xxiv.; Sacc. Syll. vii. n. 939.

*Achlya intermedia*, Bail. Krank. Insect. durch Pilze, t. ii. f. 29.

In putrefying insects in water. Rare.

### **Achlya, Nees.**

Dioecious or monœcious; oogonia smooth or strongly echinulate, polysporous, rarely unisporous; antheridia terminal on simple or divided branchlets usually springing from the hypha just below the oogonia in monœcious species; zoosporangia cylindrico-clavate, terminal, containing numerous zoogonidia arranged without order in a crowded manner, the zoogonidia are enclosed in a thin pellicle after liberation from the zoosporangia, and usually form a compact hollow sphere at the moment of escape from the zoosporangia, from which they eventually escape in the naked form. Habit of *Saprolegnia*.

*Achlya*, Nees, Nov. Act. Leop. xi. 2, p. 514; Sacc. Syll. vii. p. 274.

A. *Monœcious*.

*Achlya polyandra*, Hildebrand (fig. 31).

Mycelium branched; oogonia globose or broadly elliptical, large, up to 150  $\mu$  diameter, not perforated; oospores numerous, globose, smooth, brown, 25  $\mu$  diameter; antheridia 2—6 attached to one oogonium, terminal on simple or divided, slender, flexuous branches springing from the hypha supporting the oogonia; zoosporangia apical, cylindrical, slender, very long.

*Achlya polyandra*, Hildebrand, in Pringsheim's Jahrb. vi. t. xvi. ff. 7—11; Sacc. Syll. vii. n. 944.

On putrid insects in water. Rare.

B. *Diœcious*.

*Achlya cornuta*, Archer.\*

Plant diœcious; oogonia large, mostly terminal, often in an interrupted series, the outer wall drawn out into numerous horn-like extensions of varying and often considerable length, sometimes bifid; the apex of the terminal one drawn out generally very long, and occasionally the supporting filament or stem giving off lateral branches by a kind of proliferous growth, each of which eventually terminates in an oogonium of similar character, but usually of smaller size; oospores large, one or several in an oogonium; mother cells of spermatozoids (zoogonidia) as in *Achlya dioica*. The uppermost oogonium is the first or oldest formed, the lowest the youngest or last formed in the series.

*Achlya cornuta*, Archer, Quart. Journ. Micr. Science, vol. vii., new series (1867), p. 127, pl. vi. figs. 2—6.

The above description, without locality or habitat, is all that is known of this apparently distinct species.

### **Aphanomyces**, De Bary.

Zoosporangia very long, slender, cylindrical, zoogonidia uniseriate; oogonia usually containing one, rarely two, oospores; antheridia apical on vermiform branchlets, encircling the oogonia.

*Aphanomyces*, De Bary in Pringsh. Jahrb. ii. p. 170; Sacc. Syll. vii. p. 276.

Characterized by the slender, elongated zoosporangia, with the zoogonidia in a single row, or *uniseriate*.

*Aphanomyces stellatus*, De Bary (figs. 105—108).

Mycelium creeping, fertile branches erect, oogonia when mature spherical, stellate, 26-35  $\mu$  diameter, including the rays; oospores spherical, 15-18  $\mu$ , one, rarely two in each oogonium; gonidia at first in chains, either forming zoogonidia or producing germ-tubes.

*Aphanomyces stellatus*, De Bary, Pringsh. Jahrb. ii. p. 170, t. xix. figs. 1—13; Sacc. Syll. vii. n. 949.

On putrid insects in water. Rare.

A second species, not recorded for Britain, is parasitic within the cells of various species of *Spirogyra*.

### **Monoblepharis**, Cornu.

Mycelium aseptate, branched; oogonia terminal, sometimes appearing to be lateral owing to a continuation of growth of the hypha beyond the oogonium, the latter being laterally deflected, solitary, or superposed in chains of from 3—12; antheridia formed from the cells immediately below, and supporting the oogonia, or springing from



the wall of the latter organ, solitary or superposed; antherozoids motile, furnished with a single cilium; zoosporangia thin walled, sometimes proliferous; zoogonidia motile, uniciliate.

*Monoblepharis*, Cornu. Ann. Sc. Nat. ser. v. vol. xx. p. 84; Sacc. Syll. vii. p. 277.

Distinguished by the motile antherozoids and zoogonidia being uniciliate.

*Monoblepharis sphaerica*, Cornu. (figs. 26, 27).

Mycelium branched, aseptate, about 5  $\mu$  diameter; oogonia monosporous, terminal, solitary, rarely in pairs, globose and with an apical papilla at maturity; oospore spherical, 25-30  $\mu$  diameter, pale brown, warted; the single antheridium consists of a portion of the hypha supporting the oogonium and immediately below it, cut off from the general cavity of the hypha by a septum, antherozoids elliptical, with a long, apical cilium.

*Monoblepharis sphaerica*, Cornu. Ann. Sci. Nat. ser. v. vol. xv. p. 82, pl. ii. figs. 1-6; Sacc. Syll. vii. n. 953.

On rotten leaves in stagnant water. Rare.

Resembling in appearance a species of *Pythium* or *Saprolegnia*, but distinguished by the motile uniciliate antherozoids contained in a cut-off portion of the supporting hypha immediately below the oogonium.

#### FAM. 4. ENTOMOPHTHOREÆ.

The species included in the *Entomophthoreæ* are for the most part *entomogenous*, or parasitic on insects, but a few species not yet recorded for Britain are met with on fungi, in the prothalli of ferns, or on the

dung of frogs and lizards. All the species are structurally closely allied, and, in the entomogenous forms, are characterized by the thick hyphæ filled with oil globules and fatty contents, which emerge from between the rings of the insect's abdomen in compact white masses of gonidiophores, producing at their tips comparatively large gonidia, which at maturity are projected to a distance. These gonidia, on coming in contact with a new host, germinate at once, and propagate the disease. In addition to the gonidial mode of reproduction, thick-walled resting-spores, either zygosporos or azygosporos, are often produced, in some species in the tissues of the host, in others externally; these, after a period of rest, germinate and produce gonidia that are also discharged into the air by the sudden rupture of the supporting gonidiophores. In some species the host is firmly attached to the *substratum*, or substance upon which it rests, by specialized hyphal branches, termed *rhizoids* by Thaxter.<sup>1</sup> These rhizoids may be simple or branched, the tips being often discoid. In other cases the affected host is firmly fixed by its proboscis to the substratum. It was at one time considered that the members of the present group were stages in the life-cycle of the species of *Saprolegniæ*. For example, *Empusa muscæ* was considered as a condition of *Saprolegnia ferox*, the cause of the salmon disease. The discovery of sexually produced resting-spores in the *Entomophthoræ* has shown this view to be un-

<sup>1</sup> Entomophthoræ of the United States; Memoirs, Boston Soc. Nat. Hist., vol. iv., number vi. (1888).

tenable. Although in some instances the fungus, so far as observation goes, appears to produce no injurious effect on the insect host, yet in most cases the death of the host is the result, and it is probable that in many instances the mortality thus effected is very widespread, and as the mortality often occurs in insects injurious to plants of economic importance, a correct knowledge of the life-history of the various species of fungi forming the present group is highly important. Thaxter says, "I have observed two epidemics caused by this species [*Empusa Entomophthora*) *Sphaerosperma*, Fres.], one among certain small flies in a wood near marshy ground at Kittery, Me., where the hosts occurred in considerable numbers, fixed by the fungus on the under side of the lower leaves, a few feet from the ground. The second instance occurred in two orchards in the same locality, where the hundreds of the previously mentioned epidemic were replaced by tens of thousands, the host in this instance being the leaf-hopper (*Typhlocyba malvæ* and *rosa*), a pest only too well known to cultivators of roses. Having first observed it in some abundance on roses in a garden, I was led to make an examination of adjacent apple orchards, and found the lower branches of the trees literally covered with the affected hosts, a dozen or more being often fastened to a single leaf."<sup>2</sup> The same author describes *Entomophthora aphidis* as producing a similar wholesale destruction of the aphid so injurious to the hop plant.

<sup>2</sup> Lc. p. 173.

# ENTOMOPHTHOREÆ.

Gonidiophores simple or branched, generally emerging from the matrix; zygosporcs formed by the conjugation of two contiguous cells, or two branches of the same hypha, or arranged in a scalariform manner between two distinct hyphæ; azygosporcs are known in some species.

The members of the present family somewhat resemble the *Saprolegniæ* in habit, but are quite distinct in the mode of formation of the sexually produced resting-spores and in the gonidia not being motile. A considerable number of species are known in Europe, and undoubtedly careful research will add considerably to the number of British forms.

## Analysis of the Genera.

A. Parasitic on insects.

*Empusa*. Gonidiophores simple.

*Entomophthora*. Gonidiophores branched.

B. Saprophytic on excrement of batrachians.

*Basidiobolus*. Gonidiophores very much incrassated at the tips.

## **Empusa, Cohn.**

Mycelium developed within the living bodies of insects; gonidiophores colourless, simple, or sparingly branched, emerging in an erumpent manner after the death of the insect; gonidia terminal, smooth; resting-spores, as azygosporcs, produced from hyphæ in the body of the insect or from the germination of the gonidia.

*Empusa*, Cohn, *Hedwigia*, 1885, p. 57; Sacc. *Syll.* vii. p. 281.

The species form in most cases white, mould-like developments on the bodies of insects. Distinguished from *Entomophthora* more especially by the mode of branching of the gonidiophores, which in the present genus are simple or irregularly branched, whereas in *Entomophthora* the branching is truly digitate.

*Empusa muscæ*, Cohn. (fig. 98).

Gonidiophores simple, crowded, clavate, emerging between the segments of the host after death, gonidia terminal, subglobose, apex slightly mucronate, base truncate, colourless, variable in size,  $18-30\ \mu$ ; azygospores produced laterally or terminal on hyphæ within the host, globose, epispore thick, colourless,  $30-38\ \mu$  diameter.

*Empusa muscæ*, Cohn, Nov. Act. Acad. xxv. pt. i. p. 317; Sacc. Syll. vii. n. 968.

*Sporendonema muscæ*, Fr. Syst. Myc. iii. p. 438.

Forming a white, mould-like growth on the bodies of dead house-flies (*Musca domestica*) and other dipterous insects. Common.

Dead house-flies are frequently seen during the autumn attached to window panes by a white halo formed by the hyphæ of the present species.

*Empusa culicis*, A. Braun.

Gonidiophores clavate, simple or branched, sometimes becoming confluent in white or greenish masses, gonidia subglobose, colourless, apex apiculate, base truncate,  $8-12 \times 7-9\ \mu$ ; azygospores globose, produced laterally or terminal on hyphæ within the host, colourless,  $24-28\ \mu$  diameter.

*Empusa culicis*, A. Braun, Alg. Unicell. p. 105; Sacc. Syll. n. 969.

On various small dipterous insects. Rare.

Generally resembling *Empusa muscæ*, but the gonidia and resting-spores are much smaller. Large cystidia are mixed with the gonidiophores. The host is anchored to the substratum by numerous mycelial "rhizoids."

### **Entomophthora, Fres.**

Mycelium developing within the bodies of living insects, broadly effused, branched, after the death of the host giving origin to erumpent, digitately branched gonidiophores; gonidia colourless or coloured; resting-spores globose, hard, episporous smooth, produced within the matrix of the host, often in a scalariform manner.

*Entomophthora*, Fres. Bot. Ztg. 1856, p. 883; Sacc. Syll. vii. 1, p. 282.

The scalariform arrangement of the resting-spores is owing to conjugation taking place between two parallel hyphæ that become connected by transverse outgrowths as in the genus *Spirogyra* amongst fresh-water algæ.

### *Entomophthora aphidis*, Hoffm.

Gonidiophores digitate, branches erect, or sometimes subsimple and more or less clavate; gonidia inconstant in form, elliptical, fusiform or irregular and sometimes curved, colourless,  $24-30 \times 8-16 \mu$ ; resting-spores globose, terminal on short branches, wall double, smooth, brownish,  $30-45 \mu$  diameter.

*Entomophthora aphidis*, Hoffm. Abhandl. der Senk.

naturf. Gesells. Band ii. p. 298, tab. ix. figs. 59—67; Sacc. Syll. vii. 1, n. 975.

On various species of aphides. Not common.

The affected aphides are anchored to the substratum by a few mycelial rhizoids ending in flattened, discoid organs of attachment.

### **Basidiobolus, Eidam.**

Saprophytic; mycelium broadly expanded, thick, branched, septate; gonidiophores simple, erect, becoming broadly clavate and basidia-like at the apex which produces gonidia; resting-spores formed by the conjugation of adjoining cells in the same hypha.

*Basidiobolus*, Eidam in Schroet. Kr. Fl. Schles. Pilze, p. 224; Sacc. Syll. vii. 1, p. 285.

Distinguished amongst the genera of the *Entomophthoræ* by the peculiar habitat, on the dung of batrachians, and by the remarkably inflated, simple, basidia-like gonidiophores.

### *Basidiobolus ranarum*, Eidam.

Gonidiophores highly heliotropic, for some distance cylindrical, 13-15  $\mu$  thick, simple, becoming clavate at the tips and from 40-60  $\mu$  thick, gonidia solitary on the basidia, globose or broadly elliptical, 48-50 or 45-46  $\times$  48-50  $\mu$ ; resting-spores globose or broadly elliptical, epispore thick, undulate, smooth, consisting of several distinct layers, pale yellowish-brown or colourless, 25-45  $\mu$  diameter.

*Basidiobolus ranarum*, Eidam, in Schroeter's Krypt. Fl. Schles. p. 225; Sacc. Syll. vii. 1, n. 983.

On dung of frogs kept in confinement. Not uncommon.

## FAM. 5. CHYTRIDEE.

The present family includes a number of mostly very minute parasitic or saprophytic microscopic fungi, the greater part of which are aquatic or spend at least a portion of their vegetative period in water. A common point of agreement is the formation of sporangia of characteristic forms, the contents of which break up simultaneously into zoogonidia or swarmspores. Each zoogonidium has usually one cilium, and produces either directly after conjugating in pairs fresh sporangia, or becomes covered with a thick wall and forms a resting-spore, the contents eventually becoming transformed into a sporangium containing zoogonidia. The zoogonidia escape from the sporangium through a narrow opening, usually at the apex of the sporangium, formed by the sudden swelling and melting of a portion of the sporangial-wall, and in some species are at first involved in mucilage from which they extricate themselves one by one, in other species they leave the sporangium singly. The life-history of one species, described by Nowakowski, is summarized as follows by De Bary:<sup>3</sup>—

“*Polyphagus euglenæ* a parasite upon resting *Euglena viridis*, has become the best known of the Chytridieæ through Nowakowski’s beautiful investigations. The swarmspore, when it has come to rest in the water, becomes spherical in shape, and at once puts out hair-like tubular-rhizoid processes in indefinite directions (B). If one of these encounters a

<sup>3</sup> l.c. pp. 162-164.



resting *Euglena* (*e*) it penetrates into its body, destroying and exhausting it to supply food to the parasite. The parasite then begins to increase in size, the rhizoid-tubes become larger and thicker, and new ones are formed which throw out branches, and attack and destroy any new *Euglenæ* which they encounter. In this way a much-branched plant is formed with hair-like terminal branchlets, which connect with the larger main stems, and through these with the body of the original spore; the latter has grown in the meantime into a large round or elongated vesicle at the expense of the *Euglenæ*, which have been exhausted by the rhizoids. When it has reached a certain size, varying according to the food which has been supplied to it, it shows itself in many specimens to be a sporangium, or if the term is preferred, a *prosporangium*. It grows out at one spot into a bluntly and irregularly cylindrical thick tube with a delicate membrane, into which the whole of the protoplasm passes, and is at once divided into swarm-spores (*C*). This process of development may be repeated for many generations, and leads to an immense multiplication of individuals if there is a sufficient number of *Euglenæ* within reach. When this has taken place, the course of events changes. The young plants remain for the most part small, and become *gametes* which conjugate in pairs, each pair forming a *zygospore*, and these behave as *resting-spores*. The two conjugating gametes of a pair (*D*) have no definite position or distance with respect to one another, and are similar in form to the non-conjugating plants. The one (*b*), which from the

processes to be described may be termed the *supplying gamete* (abgebende Gamete), has usually a round and larger body, but shows no other apparent difference before contact with the other (*a*), the *receptive gamete* (aufnehmende Gamete). The latter usually continues to be smaller, and often very small, and puts out rhizoid branches, and if one of these, after longer or shorter growth, encounters a supplying gamete it applies its extremity to it as a conjugating tube (*s*), and increases in thickness, while it ceases to grow in length. The membrane between the conjugating tube and the supplying gamete disappears at the point of attachment, and an open communication between them being thus established, the whole of the united protoplasm of both gametes passes into an enlargement of the conjugation-tube, close to the point of attachment; the swelling gradually expands into a spherical vesicle, and, being delimited by a membrane after receiving the protoplasm, becomes a thick-walled zygospor (E, *s*). The outer wall of the zygospor assumes a pale yellow colour, and in some cases continues smooth, in others is covered with short spikes, which begin to form at the same time as the enlargement in the tube. The whole process of forming a zygospor, from the attachment of the conjugating-tube and the maturation of the zygospor, was completed, in the case observed by Nowakowski, in about 6—7 hours. A few instances are known of the conjugation of 2—3 receptive with one supplying gamete, and of the consequent formation of 2—3 zygospor. The zygospor, as has been already said, is a resting-spore. It germinates when its

resting time is over and produces a zoosporangium like the non-conjugating plants. (figs. 78—82).

“Polyphagus, therefore, is essentially characterized by the gametes with their rhizoids, the mode of forming the zygosporoes, and the production of the zoosporangium or of swarm-cells from it. It may be assumed to be possible for these swarm-cells to develop directly into gametes; but an indefinite number of generations of non-conjugating plants are in fact interposed between two successive gamete-generations. The gametes in each pair behave differently in conjugation, as has been shown, and the species is dioecious. Which of the two should be called the male and which the female is not easy to determine, and must not be further discussed in this place. It is evident that we have before us an intermediate case between the ordinary forms of oogamous [= gametes of equal form and size] and isogamous [= gametes of unequal size] conjugation.”

#### CHYTRIDIÆ.

Hyphæ often absent or obsolete, hence the sporangia are often destitute of mycelium, at least very soon after their formation; asexual reproduction by zoogonidia which are produced simultaneously by the partition of the protoplasm contained in the zoosporangia; after escaping from the zoosporangia, the zoogonidia become encysted and form resting-spores; single vegetative cells or pairs that conjugate also in some cases become transformed into resting-spores. Either aerial fungi parasitic on plants, rarely saprophytic, or aquatic and parasitic on algæ, fungi and infusoria.

*Analysis of the Genera.*

A. Parasitic in Phanerogams.

*Synchytrium*. Resting-spores formed in the epidermal cells.

B. Parasites or saprophytes on algæ, fungi, or dead animals, generally aquatic.

*Rhizidium*. Consisting of two superposed cells, the lower producing rhizoids.

*Polyphagus*. Parasitic on *Euglenæ*.

*Reessia*. Zoogonidia conjugating in pairs and forming resting-spores.

*Chytridium*. Consisting of a single cell, the sporangium, which is furnished with an elongated operculate beak at the apex through which the zoogonidia escape, and with rhizoids at the base. In the cells of fresh-water algæ.

*Olpidium*. Consisting of a single cell, the sporangium, furnished with a lengthened beak through which the zoogonidia escape, rhizoids absent.

**Synchytrium**, De Bary and Woronin.

Minute unicellular fungi, entirely destitute of mycelium, inhabiting the epidermal cells of living plants; reproduction by zoogonidia produced in resting-spores or sori; no sexual mode of reproduction known.

De Bary and Woronin, Ber. Nat. Ges. Frieb. iii. H. ii. S. 22; Sacc. Syll. vii. pt. i. p. 288.

A genus remarkable for the total absence of mycelium. A zoogonidium penetrates an epidermal cell of the host plant, where the protoplasm increases considerably in size, causing the epidermal cell also to increase in size and project above the surface like a

small gland. In many cases the neighbouring cells also increase in number and form a gall-like body, usually accompanied by discoloration of the tissues and formation of bright tints. The protoplasm of the parasite eventually becomes surrounded by a firm wall and forms a resting-spore. Germination of the resting-spores takes place by two distinct methods: the endospore with its contents escapes through a rupture of the episporium, remaining attached to the latter at one point, the protoplasm then breaks up into a number of closely packed cells or zoosporangia (the whole structure is known as a sorus); or secondly, the contents of the resting-spore breaks up into zoosporangia before escaping from the episporium. In the above cases resting-spores alone are formed, and all such species having resting-spores only are placed by De Bary in the subgenus *Pycnochytrium*. In the subgenus *Eusynchytrium*, in addition to the resting-spores described above, summer sori are produced which originate like the sori in *Pycnochytrium*, but form zoosporangia at once, and these summer sori are produced in succession throughout the summer; in the autumn resting-spores are produced.

Subgenus *Pycnochytrium*. Resting-spores alone present.

*Synchytrium anemones*, Woronin.

Spots minute, reddish or violet, galls hemispherical, violet, then blackish, depressed when dry; resting-spores solitary, rarely two in a cell, spherical or broadly elliptical, brown, asperate, 75-150  $\mu$  diameter.

*Synchytrium anemones*, Woronin, Bot. Ztg. xxvi. p. 101, pl. 3, figs. 31-36; Sacc. Syll. vii. n. 988.

On petioles, leaves, peduncles and even petals of *Anemone nemorosa* and *A. pulsatilla*. Not uncommon.

Generally most abundant along the nerves of the leaves, and its presence indicated to the naked eye by the scattered or clustered minute violet spots.

*Synchytrium mercurialis*, Fckl.

Galls hemispherical, vertically depressed, with a snow-white central papilla; resting-spores brown, echinulate, 30-40  $\mu$  diameter; sori oblong, grey, generally in pairs.

*Synchytrium mercurialis*, Fuckel, Symb. Myc. p. 74; Sacc. Syll. vii. n. 989.

On leaves and peduncles of *Mercurialis perennis* and *Oenothera biennis*. Not uncommon.

The galls are usually gregarious along the lines of the veins, and are of a greenish colour.

*Synchytrium aureum*, Schroet.

Galls cylindrical; often constricted in the middle, seated on golden-yellow spots which are often bordered with red; resting-spores globose, generally solitary, epispore chestnut colour, smooth, 150-250  $\mu$  diameter, filled with golden-yellow protoplasm.

*Synchytrium aureum*, Schroeter, Beitr. zur Biol. i. pt. i. p. 40, pl. 3, ff. 8—12; Sacc. Syll. vii. 998.

On leaves of *Lysimachia nummularia*, *Sanguisorba officinalis*, *Prunella vulgaris*, and *Valerianella dioica*. Rare.

Subgenus *Eusynchytrium*. Resting-spores and summer sori formed.

*Synchytrium taraxaci*, De Bary.

Spots crust-like, confluent, orange-red, galls small,

flattened, scarcely projecting above the surface of the leaf; resting-spores globose, brown, smooth, 50-80  $\mu$  diameter; sori globose or elliptical.

*Synchytrium taraxaci*, De Bary et Wor.; Beitr. Kennt. Chytrid. 1863; Sacc. Syll. vii. n. 999.

Forming orange-red or blood-red crust-like expansions on the leaves and involucre bracts of various composite plants. The galls are flattened and project very slightly above the surface of the leaf. Not uncommon.

*Synchytrium stellaria*, Fckl.

Galls hemispherical, scattered or aggregated in broad crust-like patches; resting-spores solitary or in pairs in cells of the matrix, globose, protoplasm reddish, epispore chestnut colour, thick, smooth, 50-150  $\mu$  diameter, generally about 75  $\mu$ .

*Synchytrium stellaris*, Fuckel, Symb. Myc. p. 189; Sacc. Syll. vii. n. 1001.

On stems, leaves, and sepals of *Stellaria media*. The warts are usually confluent, forming broadly expanded crust-like patches devoid of any special colour. Rare.

**Rhizidium**, A. Braun.

Sporangia sessile on the host, composed of two superposed cells, the inferior cell sterile, giving origin to rhizoids that penetrate the host; upper cell fertile, becoming transformed into a zoosporangium or a thick-walled resting-spore, which after a lengthened period of rest germinates and produces a thin-walled cell containing zoogonidia.

*Rhizidium*, A. Braun, Ueber Chytrid. 1856; Sacc. Syll. vii. 1, p. 296.

Distinguished by the two superposed cells, the lower sterile and producing rhizoids, the upper fertile.

*Rhizidium intestinum*, Schenck.

Zoosporangium globose, 35-40  $\mu$  diameter, either external or immersed in the matrix, in the latter case a beak is developed which pierces the cell-wall of the host and through which the zoogonidia escape, zoogonidia subglobose, with one long cilium; basal cell small, 5-7  $\mu$  diameter, either superficial or immersed in the host, furnished with a few elongated rhizoids, 2-3  $\mu$  thick.

*Rhizidium intestinum*, Schenck, Ueb. Vork. Zell. pl. Zopf. zur Kennt. Phycom. p. 51, t. 8, figs. 1-15; Sacc. Syll. vii. 1, n. 1024.

On species of *Chara* and *Nitella*. Rare.

*Rhizidium Westii*, Mass. (n. sp.) (figs. 36, 37).

Zoosporangium spherico-depressed, superficial, 20-25  $\mu$  diameter, sterile basal cell immersed in the host, subglobose, 6-10  $\mu$  diameter, furnished at the base with a few slender, branched rhizoids; zoogonidia broadly pyriform,  $4 \times 3$   $\mu$ , furnished at the thin end with a very slender cilium, 20-25  $\mu$  long.

Gregarious on *Spirogyra nitida* and *Cladophora glomerata*. Not uncommon.

When parasitic on a thin-walled host, as *Spirogyra*, the zoosporangium is sessile on the lower sterile cell, but when parasitic on *Cladophora*, where the cell-wall is thick and laminated, the sterile cell is situated within the innermost layer of the wall, and at the period of reproduction emits from its apex a thin



beak which pierces the cell-wall, and expands into the zoogonidium at the surface. The zoogonidium is not separated from the basal cell by a septum, but a constriction occurs at this point, or properly speaking, the reproductive cell develops by a process of budding from the lower vegetative or sterile cell. The rhizoids extend into the cell cavity.

I first became acquainted with the present species in a preparation of *Spirogyra nitida* sent years ago by my friend Mr. W. West of Bradford, but at the time did not know what it was.

### **Polyphagus, Nowak.**

Spherical cells formed by the germination of zoosporangia produce numerous rhizoids that become immersed in the substratum, these cells eventually become transformed into zoosporangia; sexually produced by the conjugation of two cells which produce a zygospore that is also a resting-spore, and which, after a period of rest, gives origin to zoogonidia similar to those contained in the asexually formed sporangia.

*Polyphagus*, Nowakowski, Beitr. Kennt. Chytr. 1876; Sacc. Syll. vii. 1, p. 302.

*Polyphagus euglenæ*, Schroet. (figs. 78—82).

Cellules of variable size, globose, ellipsoid, or curved, when globose reaching to  $37\ \mu$  diameter, when elongated, up to  $200\ \mu$  long, filled with hyaline protoplasm, rhizoids penetrating the substratum, and forming haustoria  $6\ \mu$  thick; zoosporangia ovoid, ellipsoid, or elongato-utriculiform, very variable in size, protoplasm all breaking up into zoogonidia of a

cylindrical form and rounded at both ends,  $6-13 \times 3-5 \mu$ , with a single cilium, protoplasm with oil drops; zygosporoes formed by the conjugation of two cells, globose or ellipsoid,  $20-30 \mu$  diameter, epispore thick, yellow brown, smooth or minutely aculeolate; on germination these resting-spores produce zoogonidia.

*Polyphagus euglenæ*, Schroeter, Kryht. Fl. Schles. p. 196; Sacc. Syll. vii. 1, no. 1050.

*Chytridium euglenæ*, Bail. Mykol. Bericht, 1885  
Parasitic in *Euglena viridis*. Rare.

### **Reessia, Fisch.**

Zoosporangia furnished with a long beak, situated within the cells of the host; zoogonidia conjugating in pairs and forming resting-spores which on germination produce zoosporoes.

*Reessia*, Fischer, Beitr. Kennt. Chytrid.; Sacc. Syll. vii. 1, p. 304.

Distinguished from *Chytridium* by the entire absence of rhizoids springing from the zoosporangia. Closely allied to *Olpidium*, if indeed generically distinct.

### *Reessia amæboidea*, Fisch.

Zoosporangia globose,  $25-30 \mu$  diameter, beak  $10-15 \mu$  long, protruding from the cell of the host-plant in which the zoosporangium is situated; zoogonidia broadly pyriform, uniciliate, conjugating in pairs and becoming encysted to form a resting-spore; resting-spores globose, brownish,  $12-15 \mu$  diameter.

*Reessia amæboidea*, Fischer, Beitr. Kennt. Chytrid ; Sacc. Syll. vii. 1, n. 1057.

In the cells of living plants of *Lemna minor* and *L. polyrrhiza*. Rare.

A minute fungus met with in the cells of living fronds of *Lemna*, and referred with a certain amount of doubt to the above species.

### **Chytridium, A. Braun.**

Zoosporangia formed in the cells of the matrix, furnished with simple or branched rhizoid-like branches of mycelium which spring from the base or from various points of the surface, and separated from the cavity of the sporangium by septa, zoospores uniciliate, escaping through a pore at the apex of a lengthened beak; resting-spores furnished with a double membrane, formed within the cells of the host.

*Chytridium*, A. Braun, Betrachtung. Ersch. Verjung. Nat. 1850; Sacc. Syll. vii. p. 304; Dangeard, Ann. Sci. Nat. ser. vii. vol. iv. p. 293.

Distinguished from *Synchytrium* by the presence of mycelium attached to the zoosporangia.

### *Chytridium helioformis*, Dang.

Zoosporangia globose, 10-14  $\mu$  diameter, furnished with a long beak; rhizoids five or six in number, simple or slightly branched, springing from basal portion; zoospores globose, about 3  $\mu$  diameter; resting-spores spherical, 14-18  $\mu$  diameter.

*Chytridium helioformis*, Dangeard, Ann. Sci. Nat. ser. vii. vol. vi. p. 293; Sacc. Syll. vii. n. 1079.

In the interior of species of *Chara*, *Nitella*, and *Vaucheria*.

The long beak to the zoosporangium suggests the genus *Olpidium*, which, however, differs in the total absence of rhizoids.

### *Olpidium*, A. Br.

Zoosporangia globose or elliptical, parasitic in the interior of cells of the host without a trace of mycelium, furnished with one or more beaks through which the zoospores escape; resting-spores with a thick, smooth membrane.

*Olpidium*, A. Braun, Ueber Chytrid. in Monatsber. Kön. Preuss. Akad. der Wiss. 1855; Dangeard, Ann. Sci. Nat. ser. vii. vol. iv. p. 284; Sacc. Syll. vii. p. 310.

The total absence of rooting mycelium and presence of a beak to the zoosporangia are the principal distinctive features of the present genus.

### *Olpidium lemnæ*, Schroet.

Zoosporangia globose, usually solitary in the cells of the host, furnished with a lengthened cylindrical beak, 12-18  $\mu$  diameter; resting-spores globose, wall thick, smooth, almost colourless, 12-20  $\mu$  diameter.

*Olpidium lemnæ*, Schroet. Fl. Schles. p. 181; Sacc. Syll. vii. n. 1091.

In epidermal cells of *Lemna minor*. Probably not uncommon.

### MYCOMYCETES.

The *Mycomycetes*, or higher non-sexual fungi of Brefeld, are connected with the *Phycomycetes*, or lower,

algal-like, sexual fungi, by the *Protomycetæ* and the *Ustilagineæ*. According to Brefeld the *Protomycetæ* are genetically related to the *Mucorini*, the kinship being indicated by the homology presented between the asexual mode of reproduction in the two families; in the *Mucorini* the sexual mode of reproduction is by conjugation, the asexual mode by the production of sporangia containing gonidia. In the *Protomycetæ* the sexual mode of reproduction is entirely suppressed, and the asexual method agrees with that of the *Mucorini* in being a sporangium containing a number of gonidia, hence we may consider the *Protomycetæ* as a side branch of the *Mucorini* characterized by the total arrest of the sexual mode of reproduction, and shadowing in the evolution of an enormous assemblage of fungi characterized by producing the spores in asci or modified sporangia, and known collectively as the *Ascomycetes*.

The *Ustilagineæ* in like manner are genetically allied to the *Chaetocladiaceæ*. In the latter family the sexual form of reproduction is by zygospores; in the asexual form the slender gonidiophore is repeatedly branched towards the apex, the lateral branchlets of the last order swell into irregularly capitate, basidia-like bodies with 8—20 short, slender sterigmata, each producing a spore at its apex. In the *Ustilagineæ*, as in the *Protomycetæ*, the sexual condition is entirely arrested, and the asexual mode of reproduction is mostly confined to the formation of thick-walled resting-spores or *chlamydospores*, produced singly or in clusters on slender branches which are considered as incipient basidia, hence the *Ustilagineæ* are con-

considered as imperfectly developed *Basidiomycetes* in which the characteristic features of the group, basidia, are not yet differentiated, and the stipes and pileus not yet shadowed in.

#### PROTOMYCETÆ.

The mycelium is for the most part intracellular in the tissues of phanerogams, vaguely branched, transversely septate, and produces numerous intercalary, thick-walled resting-spores or chlamydospores, after which it disappears. Gonidia are unknown. The resting-spores are globose or broadly elliptical, in germination the thin endospore escapes entire through a rupture in the thick wall of the resting-spore as a sporangium filled with numerous, minute, cylindrical, motionless spores which conjugate in pairs either as they leave the sporangium, or by coming in contact in water. After conjugation the spores germinate by the emission of a slender germ-tube, which enters the tissues of the host plant, and at once produces a mycelium which gives origin to resting-spores. The masses of resting-spores often form hard, tubercular swellings on the host.

#### **Protomyces, Unger.**

Parasitic in the subepidermal tissues of living plants, usually forming coloured spots or patches, resting-spores terminal or intercalary, wall thick, usually consisting of two distinct layers, hyaline or coloured.

*Protomyces*, Unger, *Exanth.* p. 341; Plow. *Brit. Ured. and Ustilag.* p. 300; Sacc. *Syll.* vii. pt. i. p. 319.

Somewhat resembling in habit the genus *Synchytrium*, but distinguished by the presence of mycelium. Gonidial forms of reproduction are unknown.

*Protomyces macrosporus*, Unger (fig. 50, 51).

Spores usually aggregated in scattered, oblong or subglobose, gibbous spots, which are at first pale and translucent, then brown; spores subglobose or elliptical, 30-80  $\mu$  diameter, epispore pale yellow, smooth, 3-5  $\mu$  thick; sporidia cylindrical, colourless, 2-2.5  $\times$  1  $\mu$ .

*Protomyces macrosporus*, Unger, Exanth. der Pflanze, p. 344, t. vi. f. 34; Sacc. Syll. vii. n. 1120; Plow. Brit. Ured. and Ustilag. p. 300.

On living stems and petioles more especially of *Ægopodium podagraria*, *Daucus carota*, *Heracleum sphondylium*, *Anthriscus sylvestris*, *Apium nodiflorum*, *Meum anthelminticum*, *Angelica sylvestris*, *Ænanthe crocata*. Common.

Dr. R. Caspary suspects that the present species is nothing more than the oosporic condition of *Peronospora umbelliferarum* (= *Plasmopara nivea*, Schroet.); see Berlin Bericht über die zur Bekaunt, 1855.

*Protomyces rhizobius*, Trail.

Resting-spores spherical, 30-33  $\mu$  diameter, epispore subhyaline or pale brown, 10-12  $\mu$  thick; in the cortex of the root, in groups of from 2-8, mixed with delicate mycelium.

*Protomyces rhizobius*, Trail. Scot. Nat. 1884, p. 125; Sacc. Syll. vii. n. 1138; Plow. Brit. Ured. and Ustilag. p. 300.

On the roots of *Poa annua*. Rare.

*Protomyces pachydermus*, Thum.

Spots rather prominent, elliptical or subglobose, brown, at first covered by the epidermis, then erumpent; resting-spores subglobose or broadly elliptical, 14-24  $\mu$  diameter, epispore pale brown, smooth, 3-4  $\mu$  thick.

*Protomyces pachydermus*, Thum. Hedw. 1874, p. 97; Sacc. Syll. vii. n. 1121; Plow. Brit. Ured. and Ustilag. p. 300.

On living petioles and leaves of *Daucus carota* and *Taraxacum officinale*. Not common.

Resembling *P. macrosporus* in habit, but distinguished by the smaller spores.

*Protomyces menianthis*, De Bary.

Forming scattered or confluent small, wart-like patches, at first reddish, then brown; resting-spores solitary or several in the cells of the host, globose, elliptical, or angular from mutual pressure, epispore thick, brown, smooth, 20-40  $\mu$  diameter.

*Protomyces menianthis*, De Bary, Unters. über d. Brandpilze; Plow. Brit. Ured. and Ustilag. p. 301.

*Physoderma menianthis*, Sacc. Syll. vii. n. 1119.

On living leaves of *Menianthes trifoliata* and *Comarum palustre*. Not uncommon.

*Protomyces ari*, Cke.

Resting-spores aggregated in large, irregular, bleached patches on the petioles and leaves, not prominent; spores usually numerous, broadly elliptical or



subglobose, often subangular from mutual pressure, epispore thin, clear brown, smooth, 14-20  $\mu$  diameter.

*Protomyces ari*, Cooke, Grev. i. p. 7; Plow. Brit. Ured. and Ustilag. p. 301; Sacc. Syll. vii. n. 1133.

(Type in Herb. Kew.)

On leaves and petioles of *Arum maculatum*. Rare.

The groups of spores are frequently arranged in large discoloured patches spreading in an irregular manner over the greater portion of the leaf. May prove to belong to the genus *Entyloma*.

*Protomyces purpureo-tingens*, Mass. (n. sp.). (figs. 72, 73).

Forming elongated or broadly effused patches of a dark purple colour on the leaves; resting-spores solitary, rarely two, globose or broadly obovate, often with a short persistent portion of the mycelium, epispore bright brown, of two distinct layers, minutely warted, 25-28  $\mu$  in diameter or 22-28  $\mu$ .

In the cotyledons and young leaves of the sunflower and of garden specimens of *Smilacina*. Rare.

The blotches in some instances cover nearly the whole of the leaf, and are of a deep purple, or in some instances almost black.

Distinguished by the warted resting-spores.

#### USTILAGINEÆ.

The members of the *Ustilagineæ* are minute parasitic fungi, mostly met with in the tissues of flowering plants. Their mycelium is very delicate,

colourless, and septate, frequently present in every part of the host, occupying the intercellular spaces and ramifying between the cells, or in some cases piercing the walls and entering the cells. Haustoria are produced by the mycelium of some species. The resting-spores, or *teleutospores* as they are sometimes called, are either formed from the ordinary mycelium or from specialized branches, and are either naked or enclosed in a special closed receptacle. In the genus *Entyloma* spores are produced from all parts of the vegetative mycelium; the first indication of spore-formation is the presence of spherical swellings which increase in size for some time, and may be terminal or intercalary; from the protoplasm contained in these swellings the spores are differentiated, and form their own cell-wall while yet enclosed within the wall of the hypha. The spores are usually produced in a concatenate manner, and remain in the tissues of the host, not becoming dry and powdery at maturity. In some species the wall has an outer gelatinous layer formed by the wall of the mother hypha, which is persistent on the true wall of the spore. In the genus *Ustilago* the spores are produced by special branches, *sporogenous hyphæ*, which are very much branched and produced in great numbers at definite spots in the tissues of the host. These special spore-producing hyphæ become cut up into isodiametric portions by transverse septa, at the same time the walls swell strongly and form a gelatinous membrane enclosing the protoplasm, which develops into a spore with its own cell-wall while yet enclosed in the gellified wall of the hypha, which eventually dis-

appears and the mature spores form a dry, powdery mass. In the genera *Urocystis*, *Tubercinia*, and *Sorosporium* the spores are compacted into permanent clusters, and surrounded by a special envelope which either soon disappears, or persists as a protective coat until the spores germinate. In *Urocystis* this envelope consists of sterile cells which surround the central cluster of spores. In *Doassansia* the clusters of spores are enclosed in receptacles consisting of closely compacted, dark coloured, sterile cells arranged in a single layer like the palisade cells of a leaf. De Bary has shown that in *Sphacelotheca hydropiperis*, which infests the ovules of *Polygonum hydropiper*, the sporophore is still more complex, being furnished with a thick outer wall, and a central axis or *columella*, the spores being formed in the space between the two. The spores at maturity are generally some shade of brown, and often opaque, and the epispore in many species is ornamented with warts, spines, or ridges which are often combined to form a network. The spores described above are resting-spores, but gonidia are also produced by some species. The details of germination of the resting-spores furnish important systematic characters, and will be described under the several generic diagnoses; in the present place it is sufficient to state that the first product of germination is a short germ-tube, the *promycelium*, which soon gives origin to small spore-like bodies called *primary sporidia*. A very remarkable feature about these primary sporidia is that they almost invariably conjugate in pairs; that is, adjacent pairs become organically united by a short tube

growing from one and becoming blended with the other, thus placing the protoplasm of the two sporidia in direct communication. In some instances conjugation takes place before the primary sporidia break away from the promycelium. After conjugation a slender germ-tube is formed which receives all the protoplasm from the two united sporidia, and if developed upon the proper host plant, penetrates into its tissues and forms a mycelium which in turn produces a new crop of resting-spores. In some species the process is more complicated; the germ-tubes produced by the primary sporidia after conjugation, give origin to a second set of sporidia, *secondary sporidia*, these in turn produce germ-tubes capable of penetrating the tissues of the host, and giving origin to resting-spores. The above mode of development takes place when the resting-spores germinate in pure water, but when germination takes place in a nutrient solution Brefeld has shown that the results are quite different; instead of a short promycelium producing secondary sporidia that conjugate at once, the promycelium continues to grow into a dense branched mycelium which eventually produces sporidia, either in the liquid or on branches that rise into the air; or the promycelium continues to develop, like the *sprouting fungi*, by gemmation or the production of numerous, minute, elliptical cells which become detached as in the genus *Saccharomyces*. The sporidia produced in a nutrient solution do not conjugate. De Bary considers the conjugation of primary sporidia produced under normal conditions, that is in water, as a sexual act, a view opposed by

Brefeld, who considers the pairing of the primary sporidia as analogous to the blending of distinct branches of mycelium already described as taking place in the mycelium of *Botrytis* and other fungi, and as not being of a sexual nature.

The special parts in which spores are formed is constant in each species, in most instances some portion of the flower, more especially the ovary is the portion where the reproductive organs of the fungus are developed, the spores at maturity forming a black soot-like mass, as in wheat, oats, barley, and other grasses, and popularly known as "smut," "brand," &c. In other species the sori, or heaps of spores, are constantly formed in the tissues of the leaves or stem, becoming exposed by the rupture of the cuticle at maturity. In the classification of Fries the *Ustilagineæ* were included along with the *Uredineæ* under the division *Hypodermii*, on account of resemblances in habitat and appearance in the mature condition. This arrangement was shown by De Bary<sup>4</sup> to be erroneous. True reproductive organs are so greatly suppressed, and never of functional value in the *Ustilagineæ* that the species are conspicuous owing to the excessive development of resting-spores, or *chlamydospores* as they are called by Brefeld, and the sporophores supporting the terminal resting-spores in *Entyloma* and *Tilletia* closely resemble basidia, and hence show a transition to the *Basidiomycetes*.

According to Ed. Fischer<sup>5</sup> the genus *Graphiola* belongs to the *Ustilagineæ*. If this idea is corroborated,

<sup>4</sup> Brandpilze, p. 28 (1853).

<sup>5</sup> Beitr. z. Kenntn. d. Gattung *Graphiola*, Bot. Ztg., 1883.

we have in the present group a greater differentiation of the sporophore than that met with in the genus *Sphacelotheca*, and accompanied by a special arrangement for spore dissemination. Finally, Professor Marshall Ward has shown that<sup>6</sup> *Schinzia leguminosarum*, Frank, which forms hard, irregular swellings on the roots of various leguminous plants, is allied to the *Ustilagineæ*.

#### USTILAGINEÆ.

Fungi for the most part parasitic in the aerial portions of living plants; mycelium usually widely extended in the host but soon disappearing; resting-spores produced within the hyphal filaments which often become gelatinous and deliquescent; gonidial modes of reproduction are present in some few species; the resting-spores on germination produce a slender continuous or sparsely septate promycelium which bears primary sporidia at the apex or laterally, the sporidia often conjugate in pairs and afterwards germinate, the germ-tube either directly penetrating the host, or producing secondary sporidia which infect the host plant. In nutritive solutions the resting-spores often produce yeast-like cells in great numbers.

#### *Analysis of the Genera.*

##### I. Resting-spores solitary.

Resting-spores not aggregated in clusters.

A. Sori not covered with an involucre formed of hyphæ.

† Sporidia generally produced laterally on the promycelium, rarely at the apex.

<sup>6</sup> Phil. Trans. Roy. Soc., 1887, p. 539.

*Ustilago*. Sori pulverulent at maturity.

†† Sporidia numerous, produced at apex of promycelium.

§ Sori pulverulent at maturity.

*Tilletia*. Resting-spores with the epispore generally reticulated.

§§ Sori not pulverulent at maturity.

a. On stems or leaves.

*Entyloma*. Sori pale or brown.

*Melanotænium*. Sori broadly expanded, black.

b. On roots.

*Entorrhiza*.

B. Sori covered with an involucre formed of hyphæ.

*Sphacelotheca*.

II. Resting-spores aggregated in clusters.

A. All the spores in a cluster of uniform size.

† Sporidia mostly apical on the septate promycelium; sori forming brownish spots, generally on leaves.

\* Sporidia numerous.

*Doassansia*. Sori covered with a continuous layer of sterile cells.

*Tubercinaria*. Sori not covered with a special layer of sterile cells.

\*\* Sporidia solitary.

*Thecaphora*. Sori rufescent; generally in the fruit or seed.

†† (Sporidia unknown), promycelium very slender.

*Sorosporium*. Sori black.

B. The cells or spores of different sizes, forming clusters.

*Urocystis*. Central resting-spores of a spore-cluster large, thick-walled, fertile, peripheral cells smaller, thin-walled, barren.

### **Ustilago, Pers.**

Vegetative mycelium spreading in the tissues of the host, soon disappearing; sporogenous hyphæ branched, resting-spores formed in the interior of much gelatinized, clustered, terminal branches. On germination the resting-spores give origin to a short, septate promycelium which produces minute terminal and lateral primary sporidia.

*Ustilago*, Pers., Sacc. Syll. vii. pt. ii. p. 451; Plow. Brit. Ured. and Ustilag. p. 272.

Many species form long, brown or blackish streaks on leaves or stems, others develop in anthers which then present a blackened, powdery appearance, others again develop in the ovaries of plants.

#### *A. Resting-spores smooth or warted.*

##### *Ustilago longissima*, Tul.

Forming long, brown, powdery streaks on the leaves; resting-spores globose or irregularly and broadly elliptical, pale brown, usually with an olive tinge, smooth, 3-4  $\mu$  diameter, or 3-4  $\times$  6-7  $\mu$ ; promycelium fusoid, narrow at the point of origin from the spore, sporidia fusiform.

*Ustilago longissima*, Tulasne, Mem. sur les Ustilag. Ann. Sci. Nat. 1847, 76; Cke. Micr. Fung. t. v. figs. 105—107; Plow. Brit. Ured. and Ustilag. 272; Sacc. Syll. vii. n. 1637.

Forming thin parallel streaks, often several inches



in length, on living leaves of *Glyceria fluitans*, *G. aquatica*, and *Phalaris arundinacea*. Common.

*Ustilago hypodytes*, Fr.

Produced on the culms, concealed at first by the leaf-sheaths, resting-spores blackish, with an olive tinge in the mass, soon pulverulent, globose, or irregularly angular or elongated, pale brown, smooth, 3-6  $\mu$  diameter, sometimes a few are present much larger than usual.

*Ustilago hypodytes*, Fr. Syst. Myc. iii. p. 518; Cke. Micr. Fung. t. v. figs. 100, 101; Plow. Brit. Ured. and Ustilag. p. 273; Sacc. Syll. vii. pt. ii. n. 1641.

Originating as long streaks on the culms below the leaf-sheaths which soon become swollen by the mass of spores. On *Triticum repens*, *T. junceum*, *Avena flavescens*, *Elymus arenarius*, *Bromus erectus*, *Phragmites communis*, *Psamma arenaria*. Not uncommon.

*Ustilago segetum*, Ditm.

Developing in the inflorescence which is soon covered with a powdery, olive-black mass; resting-spores globose or irregularly angular, pale brown, smooth or obscurely granular, 5-10  $\mu$  diameter.

*Ustilago segetum*, Ditm. in Sturm's Deutschl. Fl.; Sacc. Syll. vii. ii. n. 1676; Plow. Brit. Ured. and Ustilag. p. 273; Cke. Micr. Fung. pl. v. figs. 98, 99.

On *Festuca pratensis*, *Avena flavescens*, *A. elatior*, *A. sativa*, *Triticum vulgare*, *Aira cæspitosa*, *Hordeum vulgare*, *H. murinum*, *H. distichum*, *Lolium perenne*. Not uncommon.

*Ustilago grandis*, Fr.

Appearing as long streaks on the culms beneath the leaf-sheaths, soon becoming black and powdery; resting-spores globose, angular, or elongated, pale brown, smooth, 6-8 or 8-14  $\times$  6-9  $\mu$ ; promycelium cylindrical, narrow at the point of attachment to the spore 2-3 septate, sporidia terminal and lateral, subfusiform.

*Ustilago grandis*, Fr. Syst. Myc. iii. p. 515; Sacc. Syll. vii. ii. n. 1642; Cke. Mier. Fung. t. vi. figs. 129, 130; Plow. Brit. Ured. and Ustilag. p. 275.

On *Phragmites communis*, *Typha latifolia*, *T. minor*. Not uncommon.

*Ustilago procumbens*, B. and Br. figs. 96, 97.

Forming equidistant, encircling black bands from 2-3 mm. long on the culms, resting-spores globose or subangular, pale brown, smooth, 2.5-3  $\mu$  diameter.

*Ustilago procumbens*, B. and Br. Ann. Nat. Hist. n. 488; Cke. Mier. Fung. t. vi. figs. 120, 121; Plow. Brit. Ured. and Ustilag. p. 275; Sacc. Syll. vii. ii. n. 1635.

(Type in Herb. Berk. Kew.)

On culms of *Glyceria fluitans*, *G. squarrosa*, *Aiza acutiflora*. Remarkable in its habit of growing in bands round the culm, the bands are composed of distinct parallel streaks. Rare.

*Ustilago marina*, Durieu.

Forming irregular, wart-like excrescences on the

roots of the host; resting-spores brown, very variable in form, globose or irregularly elongated,  $10-13\ \mu$  or  $14-17 \times 10\ \mu$ .

*Ustilago marina*, Durieu, Ann. Sci. Nat. 1866; Grevillea, v. 14, p. 90; Plow. Brit. Ured. and Ustilag. p. 275; Sacc. Syll. vii. pt. ii. n. 1751.

On the roots of *Scirpus parvulus*. Does not appear to be a typical *Ustilago*. Rare.

*Ustilago hypogea*, Tul.

Forming hard, blackish, crust-like patches on the root; resting-spores globose, angular, or broadly elliptical, dark brown, smooth,  $17-20$  or  $20-24 \times 14-18\ \mu$ .

*Ustilago hypogea*, Tulasne, Fung. Hypogæi, p. 196; Grev. v. xiii. p. 52; Plow. Brit. Ured. and Ustilag. p. 276; Sacc. Syll. vii. ii. n. 1752.

On root of *Linaria spuria*. Rare.

*Ustilago caricis*, Fckl.

Forming hard, globose, black lumps within the glumes; resting-spores opaque, brown, very irregular, globose, angular, or broadly elliptical, minutely granular,  $12-17$  or  $12-30 \times 8-15\ \mu$ .

*Ustilago caricis*, Fuckel, Symb. Myc. p. 39; Sacc. Syll. vii. ii. n. 1685; Cke. Micr. Fung. t. v. figs. 96, 97; Plow. Brit. Ured. and Ustilag. p. 276.

In the inflorescence of many species of *Carex* and *Rhynchospora alba*. Not uncommon.

*Ustilago bistortarum*, Körn.

Forming large, wart-like lumps on the leaves, seated on discoloured spots, soon bursting, and then violet-

black; resting-spores globose or broadly elliptical, pale brown, minutely warted,  $14-20$  or  $17-20 \times 10-14 \mu$ .

*Ustilago histortarum*, Körn. Hedw. 1877, p. 88 Plow. Brit. Ured. and Ustilag. p. 277; Sacc. Syll. vii. 2, n. 1710.

On living leaves of *Polygonum historta* and *Rumex obtusifolius*. Rare.

*Ustilago olivacea*, Tul.

Appearing in the inflorescence, becoming pulverulent, dark brown with olive tinge; resting-spores very variable in form and size, globose, angularly globose, broadly elliptical or elongated, pale brownish-olive, smooth, or sometimes minutely granular, the spherical spores measure about  $5-6 \mu$  diameter, the elongated forms reach to  $16 \times 6 \mu$ ; promycelium minute, fusoid, aseptate.

*Ustilago olivacea*, Tulasne, Ann. Sci. Nat. p. 88 (1847); Sacc. Syll. vii. ii. n. 1682; Plow. Brit. Ured. and Ustilag. p. 277; Cke. Hdbk. p. 513; Cke. Micr. Fung. t. vi. figs. 126, 127.

In the inflorescence of *Carex riparia*. Not uncommon.

*Ustilago bromivora*, Fisch. de Waldh.

Produced in the inflorescence, soon becoming pulverulent, black; resting-spores globose, broadly elliptical, or angularly globose, dark brown, epispore very minutely granular,  $8-14 \times 6-10 \mu$ ; promycelium short, 1-septate, sporidia terminal or lateral, fusoid.

*Ustilago bromivora*, Fischer de Waldheim, Aperçu,

22; Plow. Brit. Ured. and Ustilag. p. 278; Sacc. Syll. vii. ii. n. 1677; Cke Micr. Fung. ed. 4, p. 230.

In the inflorescence of *Bromus mollis*, *B. maximus*, *B. secalinus*, *B. madritensis*. Not uncommon.

*Ustilago maydis*, Corda.

Produced in the female inflorescence and on the leaves and stem, soon becoming dusty, brown with a tinge of olive in the mass; resting-spores globose, broadly elliptical, or sometimes elongated, pale, clear brown, epispore thickly covered with minute, pointed warts,  $10-12$  or  $8-13 \times 6-10 \mu$ ; promycelium filiform, cylindrical, septate, sporidia fusoid, springing from the apex and laterally; in a nutritive solution the budding spores are large, elongato-fusiform,  $13-36 \times 3-5 \mu$ .

*Ustilago maydis*, Corda, Icones, vol. v. p. 3; Sacc. Syll. vii. ii. n. 1723; Plow. Brit. Ured. and Ustilag. p. 278; Cke. Hdbk. p. 513; Cke. Micr. Fung. t. v. f. 108.

On Indian corn (*Zea mays*). Rare in this country, but too abundant where maize is extensively cultivated.

*Ustilago vinosa*, Tul.

Produced in the ovary and filling the fruit with a black powdery mass; resting-spores globose or broadly elliptical, very pale violet or sometimes colourless, epispore coarsely warted,  $8-10$ , or  $10-12 \times 7-9 \mu$ .

*Ustilago vinosa*, Tulasne, Mem. sur les Ustilag. p. 96; Berk. ms., Sacc. Syll. vii. ii. n. 1711; Plow. Brit. Ured. and Ustilag. p. 278; Cke. Hdbk. p. 514; Cke. Micr. Fung. ed. 4, p. 230.

(Type in Herb. Berk., Kew, n. 4722.)

In the fruit of *Oxyria reniformis*. Rare.

The infected fruit is much larger than the normal form, of a bright chestnut colour, and remains closed for a long time, when crushed, the profuse powdery mass of resting-spores resembles soot on the fingers. Germination unknown.

*Ustilago salveii*, B. and Br. (fig. 85).

Sori forming long streaks on the leaves, at first covered by the epidermis, then pulverulent, brown; resting-spores globose, pale brown, covered with rather large, distant, hemispherical warts, 9-14  $\mu$  diameter; germination unknown.

*Ustilago salveii*, B. and Br. Ann. Nat. Hist. no. 482; Cke. Hdbk. p. 514; Cke. Micr. Fung. t. vi. figs. 117—119.

*Tilletia striiformis*, Sacc. Syll. vii. ii. no. 1774 (in part); Plow. Brit. Ured. and Ustilag. p. 284 (in part).

(Type specimen in Herb. Berk., Kew, n. 4738.)

On leaves of grass. Rare.

The present species has been referred to *Tilletia striiformis*, Magnus, by various authors, but an examination of the type specimen shows it to be quite distinct; it is, however, morphologically closely allied to *Ustilago macrospora*. The generic position is

uncertain, owing to absence of information respecting germination.

*B. Resting-spores reticulated.*

*Ustilago scabiosæ*, Wint.

Produced in the anthers and soon covering the whole inflorescence with a powdery mass varying from pale pink, through brownish lilac to violet; resting-spores globose, angularly globose, or broadly elliptical, almost colourless, epispore furnished with thin, slightly raised ridges combined to form a fine-meshed network, 10-13, or 8-10  $\times$  10-15  $\mu$ , sometimes much larger, reaching to 17-20  $\mu$  long; promycelium cylindrical, usually 3-septate, sporidia elliptical, produced apically and laterally.

*Ustilago scabiosæ*, Winter, Die Pilze, p. 99; Sacc. Syll. vii. ii. n. 1733; Plow. Brit. Ured. and Ustilag. p. 279.

*Farinaria scabiosæ*, Sow. Eng. Fung. t. 396, f. 2.

*Ustilago flosculorum*, Tulasne, Cke. Hdbk. p. 515; Cke. Micr. Fung. t. vi. figs. 123—125.

*Uredo flosculorum*, Winter, Die Pilze, p. 99; Plow. Brit. Ured. and Ustilag. p. 279.

*Ustilago scabiosæ*, Winter, Sacc. Syll. vii. i. n. 1733.

*Ustilago succisæ*, Cke. Micr. Fung. ed. 4, p. 230.

On the anthers of *Scabiosa arvensis*, *S. columbaria*, *S. succisa*. Not uncommon.

*Ustilago utriculosa*, Tul.

Formed in the flowers which become in consequence much distended, at length powdery, violet-black; resting-spores globose, violet, translucent,

epispore with thin ridges  $2.5-3\ \mu$  high, combined to form an irregularly polygonal network, meshes  $9-12\ \mu$  diameter; promycelium cylindrical, 3-septate sporidia elliptical, produced laterally.

*Ustilago utriculosa*, Tulasne, Mem. sur les Ustilag. p. 102, t. iv. figs. 2—6; Sacc. Syll. vii. ii. n. 1737; Plow. Brit. Ured. and Ustilag. p. 280; Cke. Hdbk. p. 514; Cke. Micr. Fung. t. vi. figs. 112—116.

On *Polygonum lapathifolium*, *P. persicaria*, *P. hydropiper*, *P. aviculare*, *P. convolvulus*. Not uncommon.

#### *Ustilago violacea*, Fuckel.

Produced in the anthers, soon becoming powdery, blackish-violet; resting-spores subglobose, lilac, epispore with ridges about  $2\ \mu$  high, combined to form an irregular network with meshes  $6-9\ \mu$  across; promycelium fusiform, generally 3-septate, sporidia elliptical, produced at the apex and laterally.

*Ustilago violacea*, Fuckel, Symb. Myc. p. 39; Sacc. Syll. vii. ii. n. 1731; Plow. Brit. Ured. and Ustilag. p. 280.

*Ustilago antherarum*, Cke. Hdbk. p. 515; Cke. Micr. Fung. t. v. figs. 102—104.

On *Silene indata*, *S. nutans*, *S. maritima*, *Saponaria officinalis*, *Cerastium viscosum*, *Pinguicula alpina*, *Stellaria graminea*, *S. Holostea*, *Lychnis diurna*, *L. vespertina*, *L. fls-cuculi*. Common.

#### *Ustilago major*, Schroet.

Produced in the anthers, becoming pulverulent, violet-black; resting-spores globose or elongated, violet, epispore with ridges about  $1\ \mu$  high, com-



bined to form a very fine network, meshes about  $1\ \mu$  across,  $7-13 \times 7-9\ \mu$ .

*Ustilago major*, Schroeter, Krypt. Fl. Schles. p. 273; Sacc. Syll. vii. ii. n. 1740; Plow. Brit. Ured. and Ustilag. p. 281.

On *Silene otites*. Rare.

*Ustilago Kühneana*, Wolff.

Produced in the inflorescence, also on the stem and leaves in the form of spots or lines, rusty-violet in the mass; resting-spores globose, violet, epispore with slightly raised ridges combined to form a fine network,  $10-16\ \mu$  diameter; promycelium 2—3 septate, sporidia very minute.

*Ustilago Kühneana*, Wolff, Bot. Zgt. 1874, p. 814; Sacc. Syll. vii. ii. no. 1730; Plow. Brit. Ured. and Ustilag. p. 281; Cke. Micr. Fung. ed. 4, p. 231.

On *Rumex acetosa* and *R. acetosella*. Rare.

*Ustilago tragopogi*, Schroet. (fig. 120).

Produced in the inflorescence, violet-black; resting-spores globose or angularly globose, blackish violet, opaque, epispore furnished with a very delicate network,  $12-18 \times 9-14\ \mu$ ; promycelium cylindrical, 3-septate, sporidia elliptic-oblong, conjugating in pairs.

*Ustilago tragopogi*, Schroeter, Kr. Fl. Schles. p. 274; Sacc. Syll. vii. ii. no. 1739; Plow. Brit. Ured. and Ustilag. p. 281; Cke. Hdbk. p. 515; Cke. Micr. Fung. ed. 4, t. v. figs. 92—95.

On *Tragopogon pratensis*. The whole of the in-

florescence is destroyed by the parasite, and the involucre remains closed. Not common.

*Ustilago cardui*, Fisch. v. Wald.

Produced in the inflorescence, brown in the mass ; resting-spores globose or broadly elliptical, violet, with very high ridges combined to form a network,  $15-20 \times 10-15 \mu$  ; promycelium cylindrical, septate, sporidia ovoid.

*Ustilago cardui*, Fischer von Waldheim, Bull. Soc. Nat. Moscow, 1867, v. i. ; Sacc. Syll. vii. ii. n. 1738 ; Plow. Brit. Ured. and Ustilag. p. 282 ; Cke. Micr. Fung. ed. 4, p. 231.

On *Carduus acanthoides*. Rare.

**Sphacelotheca**, De Bary.

Resting-spores contained in a distinct receptacle, furnished with a columella, and becoming open at the apex, solitary ; promycelium cylindrical, triseptate, producing sporidia laterally that conjugate in pairs.

*Sphacelotheca*, De Bary, Vergleich. Morph. Pilze, p. 187 ; Schroeter, Pilze Schles. p. 274 ; Plow. Brit. Ured. and Ustilag. p. 282 ; Sacc. Syll. vii. ii. p. 499.

Readily recognized by the highly differentiated receptacle and columella formed of fungal elements.

*Sphacelotheca hydropiperis*, De Bary (fig. 101).

Produced in ovaries which become more or less swollen, projecting in a horn-like manner, eventually opening at the apex and becoming pulverulent, blackish violet ; resting-spores globose, angularly

globose, or variously elongated, violet - brown, minutely verruculose, sometimes almost smooth, 7-12 or 10-20  $\times$  8-11  $\mu$ ; promycelium cylindrical, 3-septate, sporidia elliptic, produced laterally in considerable quantities, conjugating in pairs.

*Sphacelotheca hydropiperis*, De Bary, Morph. Pilze, p. 187; Sacc. Syll. vii. ii. no. 1834; Plow. Brit. Ured. and Ustilag. p. 499.

*Ustilago Candollei*, Tul. Mém. sur les Ustilag. p. 93; Cke. Micr. Fung. ed. 4, p. 299.

In the ovaries of *Polygonum bistorta*, *P. hydropiper*, *P. persicaria*, *P. vivipara*. Not common.

### **Tilletia**, Tulasne.

Resting-spores simple on branches of the mycelium which becomes gelatinized, produced in sori or clusters that become pulverulent when mature; epispore thick, generally ornamented with raised bands combined to form a network, or warted; promycelium producing sporidia at the apex only; gonidia are formed by the mycelium in a nutritive solution.

*Tilletia*, Tul. Ann. Sci. Nat. 1874, p. 112; Plow. Brit. Ured. and Ustilag. p. 283; Sacc. Syll. vii. pt. i. p. 81.

The resting-spores on germination give origin to a septate promycelium which in turn produces at the apex a variable number of slender, elongated primary sporidia which usually conjugate or become connected in pairs by the formation of a transverse branch, thus forming H-like bodies; after conjugation small secondary gonidia are produced by the primary gonidia. The so-called conjugation is not a sexual

act of functional value, as shown by the fact that primary gonidia that have not conjugated also produce secondary gonidia capable of germination. The secondary gonidia on germination produce slender germ-tubes which enter the tissues and infect the host. Conjugation also frequently takes place between the secondary gonidia, but is not absolutely necessary in order to induce germination.

A. *Epispore* with raised bands combined to form a network.

*Tilletia tritici*, Winter (figs. 53—56).

Developing in the ovary, sori blackish or brownish olive, remaining covered by the epidermis, soon becoming pulverulent, very fetid; resting-spores globose, olive-brown, 14-20  $\mu$  diameter, ridges of epispore 1-1.5  $\mu$  high, combined to form a regular network of polygonal meshes 3-3.5  $\mu$  in diameter; primary sporidia linear, usually conjugating in pairs.

*Tilletia tritici*, Winter, Kr. Fl. p. 110; Plow. Brit. Ured. and Ustilag. p. 283; Sacc. Syll. vii. n. 1760.

*Tilletia caries*, Cke. Hdbk. p. 511; Cke. Micr. Fung. t. v. figs. 84—91.

In ovaries of *Triticum vulgare*, *T. spelta*. Common.

The infected ovaries give out a blackish, pulverulent mass of spores when crushed, which has a very unpleasant smell, especially when moistened.

*Tilletia decipiens*, Körn. (fig. 52).

Produced within the ovary and on the glumes; mass of spores black, fetid; resting-spores globose

or irregularly subrotund, rarely broadly elliptical, 25-28 or 24-26  $\times$  27-30  $\mu$ ; episore clear dark brown, with thin ridges 2.5-3  $\mu$  high, combined to form a network having meshes about 4  $\mu$  diameter; germination not known.

*Tilletia decipiens*, Körn. in Winter, Pilze, p. 111; Plow. Brit. Ured. and Ustilag. p. 284; Sacc. Syll. vii. i. n. 1762.

In the ovary and glumes of *Agrostis vulgaris*, *Agrostis alba*, and *Apera spica-venti*. When *Agrostis vulgaris* is attacked the plants are dwarfed, and were considered as a distinct species by Linnæus under the name of *Agrostis pumila*; by others the dwarfed form is reckoned as a variety of *A. vulgaris*, but it was long since shown to be only *A. vulgaris*. Not uncommon.

#### B. *Episore covered with spines.*

*Tilletia striiformis*, Magnus (figs. 83, 84).

Sori forming long, parallel, brownish-black streaks, minutely pruinose, becoming pulverulent; resting-spores globose, broadly elliptical, or irregular globose, olive-brown, episore covered with slender spines about 1  $\mu$  long, connected at the base by a delicate reticulation, 10-13, or 11-16  $\times$  8-11  $\mu$ ; primary sporidia linear, elongated, often conjugating in pairs.

*Tilletia striiformis*, Magnus, in Winter, Pilze, p. 108; Plow. Brit. Ured. and Ustilag. p. 284; Sacc. Syll. vii. i. n. 1774.

On the leaves, leaf-sheaths, and stems of various grasses belonging to the following genera, *Alopecurus*, *Avena*, *Milium*, *Holcus*, *Anthoxanthum*, *Briza*, *Poa*,

*Calamagrostis*, *Dactylis*, *Festuca*, *Bromus*, *Agrostis*,  
*Lolium*. Not uncommon.

### **Urocystis**, Rabenh.

Sori erumpent, coarsely pulverulent, blackish ; spore-clusters consisting of one or several large, thick-walled resting-spores capable of germination and surrounded more or less completely by smaller, thin-walled, sterile cells ; on germination the slender promycelium produces sporidia at the apex only.

*Urocystis*, Rabenh. in Klotzsch, Herb. Myc. ed. ii. no. 393 ; Sacc. Syll. vii. ii. p. 515 ; Plow. Brit. Ured. and Ustilag. p. 285.

#### *Polycystis*, Lév.

Readily distinguished by the spore-clusters consisting of large, thick walled, dark resting-spores surrounded by thin walled, pale, sterile cells.

### *Urocystis occulta*, Rabenh.

Sori forming long streaks on leaves, leaf-sheaths, stems, and glumes, at first covered by the epidermis, becoming powdery and black ; spore-clusters globose or elliptical,  $17-24 \times 15-20 \mu$ , central fertile spores  $9-17 \mu$  diameter, spherical or angularly compressed, smooth, obscure opaque brown, 1—3 in number, rarely more ; sterile peripheral cells in a single, interrupted layer, globose or flattened, pale brown,  $4-6 \mu$  diameter ; promycelium slender, bearing at the apex 2—6 cylindrical sporidia.

*Urocystis occulta*, Rabenh. in Klotzsch, Herb. Myc. ii. n. 393 ; Sacc. Syll. vii. ii. n. 1891 ; Plow. Brit. Ured. and Ustilag. p. 285.

*Urocystis parallela*, Cke. Micr. Fung. t. ix. figs. 167—188.

On *Avena elatior*, *Lolium perenne*, *Triticum vulgare*, *Secale cereale*, *Poa pratensis*. Not uncommon.

*Urocystis agropyri*, Schroet.

Sori forming long, parallel, black lines on the leaves; spore-clusters subglobose or broadly elliptical,  $20-26 \times 16-20 \mu$ , central resting-spores 1—5 in number,  $8-12 \mu$  diameter, peripheral sterile cells in a single, often incomplete layer,  $5-9 \mu$  diameter.

*Urocystis agropyri*, Schroet. Brand. u. Rostp. Schles. p. 7; Sacc. Syll. vii. ii. n. 1892; Plow. Brit. Ured. and Ustilag. p. 285.

*Urocystis Fischeri*, Körn. Hedw. 1877, p. 34; Plow. Brit. Ured. and Ustilag. p. 286.

On *Triticum repens*, *Avena elatior*, *Festuca rubra*, *Carex glauca*. Not common.

Closely resembling *U. occulta*, if indeed distinct; the mycelium is said to be perennial.

*Urocystis colchici*, Rabenh. (figs. 86, 87).

Sori black, forming rather large, swollen lines or patches on the leaves and stem, soon bursting the epidermis and becoming powdery; spore-clusters globose or irregular,  $20-35 \times 16-20 \mu$ , central fertile spores 1—5, roundish or angular from mutual pressure, smooth, chestnut-brown,  $4-6$  up to  $10-15 \mu$  diameter; peripheral sterile cells pale yellow-brown, often in two layers,  $7-11 \mu$  diameter.

*Urocystis colchici*, Rab. Fung. Eur. n. 396; Sacc.

Syll. vii. ii. n. 1895; Plow. Brit. Ured. and Ustilag. p. 286; Cke. Hdbk. p. 517; Micr. Fung. ed. 4, p. 232.

On *Colchicum autumnale*, *Scilla bifolia*, *Paris quadrifolia*. Not uncommon.

*Urocystis sorosporioides*, Körn.

Sori black, forming very convex pustules on the leaves, for some time covered with the greyish-white epidermis which at length ruptures and the mass becomes pulverulent; spore-clusters subglobose or oblong, compact, subopaque, variable in size,  $22-48 \times 15-21 \mu$ ; central fertile spores 4—6, rarely more, globose or hemispherical, smooth, subopaque, brown,  $11-17 \mu$  diameter; peripheral sterile cells numerous, in a single layer, rather lax, globose or hemispherico-flattened,  $7-12 \mu$  diameter, pale yellow-brown.

*Urocystis sorosporioides*, Körn. in Fckl. Symb. Myc. iii. p. 10; Sacc. Syll. vii. n. 1904; Plow. Brit. Ured. and Ustilag. p. 287; Cke. Micr. Fung. ed. 4, p. 232.

On leaves, petioles, and stems of *Thalictrum minus*. Rare.

Fungus often occupying surface of the leaves, forming small, very convex pustules; on the stem and petioles the pustules become elongated.

*Urocystis gladioli*, W. G. Smith.

Sori pustulate, black, rotund, scattered or approximated, covered at first with the inflated epidermis and surrounded by a yellow ring; spore-clusters



globose, 40-50  $\mu$  diameter; central fertile spores with the outer free portion of each convex, the contiguous surfaces flattened, brown, 3-6  $\mu$  diameter; peripheral sterile cells very numerous, regularly arranged, pellucid, pale brown.

*Urocystis gladioli*, W. G. Smith, Gard. Chron. 1876, p. 420; Sacc. Syll. vii. ii. n. 1900; Plow. Brit. Ured. and Ustilag. p. 287; Cke. Micr. Fung. ed. 4, p. 232.

On the corms and stems of *Gladiolus communis* and *G. imbricatis* in gardens. Not uncommon during certain seasons.

*Urocystis anemones*, Schroet.

Sori large, convex, circular or elongated, for some time covered by the epidermis which eventually splits longitudinally, becoming powdery, black; spore-clusters variable in size and form, 25-30  $\mu$ ; central fertile spores 1-3, rarely more, brown, minutely granulose, 16-18  $\mu$  diameter; peripheral sterile cells few in number, rarely forming a continuous layer, hemispherico-depressed, pale brown, 8-16  $\mu$  diameter; sporidia produced at the apex of the promycelium, elliptical or frequently pyriform, 10-14  $\times$  3-3.5  $\mu$ .

*Urocystis anemones*, Schroeter, in Bem. u. Beob. Ustilag. in Beitr. Biol. Pfl. 1877, p. 375; Sacc. Syll. vii. ii. n. 1901; Plow. Brit. Ured. and Ustilag. p. 288.

*Urocystis pompholygodes*, Cke. Hdbk. p. 517; Cke. Micr. Fung. t. ix. figs. 183, 184.

Forming large blisters on the stem and leaves of

*Anemone nemorosa*, *Ranunculus acris*, *R. repens*, *R. bulbosus*, *Hepatica triloba*, *Ficaria ranunculus*, *Actæa spicata*. Not uncommon.

*Urocystis violæ*, Fischer.

Sori black, often in the form of scattered pustules seated on livid patches; spore-clusters globose or elliptical,  $30-50 \times 20-45 \mu$ ; central fertile spores rarely solitary, up to eight in number, globose or subangular, obscure brown,  $10-17 \mu$  diameter; peripheral sterile cells hemispherical, pale brown,  $6-10 \mu$  diameter; promycelium short, sporidia usually numerous, cylindrical, produced at the apex of the promycelium.

*Urocystis violæ*, Fischer, Aperçu, p. 41; Sacc. Syll. vii. ii. n. 1905; Plow. Brit. Ured. and Ustilag. p. 288; Cke. Hdbk. p. 517; Cke. Micr. Fung. t. ix. figs. 185, 186.

*Granularia violæ*, Sow. Eng. Fung. t. 440.

On the stems and veins of leaves of *Viola odorata*, *V. hirta*, *V. sylvatica*, *V. tricolor*. Not uncommon.

*Urocystis primulicola*, Magnus.

Produced in the ovary, becoming pulverulent, brownish-black; spore-clusters spherical or irregular,  $21-50 \mu$  diameter; central fertile spores brown, smooth, subangular from mutual pressure, 2—6 in number, rarely as many as ten,  $9-15 \mu$  diameter; peripheral sterile cells numerous, thin-walled, pale brown, smooth,  $6-8 \mu$  diameter; promycelium cylindrical, hyaline, sporidia terminal, 1—4, ovoid or oblong, frequently pyriform, very shortly pedicellate,  $9-18 \times 4-9 \mu$ , hyaline.

*Urocystis primulicola*, Magnus, Ueber drei neue Pilze Schles. in Sitzungsber. d. Botan. Vereins. des Prov. Brandenburg, B. xx. 1871; Sacc. Syll. vii. ii. n. 1899; Plow. Brit. Ured. and Ustilag. p. 289.

On *Primula farinosa* and *P. vulgaris*. Rare.

### Entyloma, De Bary.

Mycelium intercellular, not becoming gelatinized; resting-spores solitary, terminal or intercalary, often crowded together in sori, but not forming spore-clusters, epispore thick, often stratose, hyaline or coloured, smooth or ornamented; promycelium filiform, primary sporidia acrogenous, elongated, often conjugating in pairs; in some species gonidia are produced acrogenously on slender gonidiophores which form indeterminate white tufts on the surface of the host.

*Entyloma*, De Bary, Bot. Ztg. 1874, p. 101; Sacc. Syll. vii. ii. p. 487; Plow. Brit. Ured. and Ustilag. p. 289.

Closely allied to *Melanotænium*; the latter differs in the black sori.

#### A. *Gonidia formed on the living host-plant.*

##### *Entyloma Fergussoni*, Plow.

Spots orbicular, 1—3 mm. diameter, greyish on the under surface of the leaf owing to the formation of gonidia; resting-spores globose or angularly globose from mutual pressure, rarely broadly elliptical, epispore rather thin, smooth, pale brown, 10-15  $\mu$

diameter; gonidia aseptate, cylindrical,  $30-45 \times 2.5-3 \mu$ .

*Entyloma Fergussoni*, Plow. Brit. Ured. and Ustilag. p. 289.

*Entyloma canescens*, Schroeter, in Cohn's Beitr. Biol. (1877), p. 372; Sacc. Syll. vii. ii. n. 1790.

*Protomyces Fergussoni*, B. and Br. Ann. Nat. Hist. ser. iv. vol. xv. p. 36 (Berkeley's, no. 1473) (1875); Grev. vol. xii. p. 99; Cke. Micr. Fung. ed. 4, p. 227.

(Type in Herb. Berk., Kew.)

On *Myosotis sylvatica*, *M. palustris*, *M. arvensis*, *M. cæspitosa*. Probably not uncommon.

*Entyloma bicolor*, Zopf.

Spots yellowish, rounded or oblong, expanded, 1-10 mm. or more long, brown or reddish-brown above, grey underneath; resting-spores spherical, angularly spherical or elliptical,  $17-20 \mu$  or  $24 \times 12-18 \mu$ , epispore gelatinous, colourless, then brown; gonidia cylindrical, incurved, narrow at the base, apex rounded, continuous or septate,  $10-22 \times 3 \mu$ , hyaline, produced by slender simple or branched gonidiophores forming whitish tufts on the under surface of the leaf.

*Entyloma bicolor*, Zopf, in Rab. Fung. Eur. n. 2496; Sacc. Syll. vii. ii. n. 1792; Plow. Brit. Ured. and Ustilag. p. 290.

On *Papaver rhæas* and *P. dubium*. Rare.

*Entyloma ranunculi*, Schroet. (figs. 116, 117).

Spots more or less orbicular, variable in size, 1-7 mm. diameter, often several on the same leaf,

whitish, then yellow or brownish, at first producing the gonidia; resting-spores globose, epispore smooth, about  $1\ \mu$  thick, pale brown, 11-14  $\mu$  diameter; gonidia colourless, continuous, elongato-fusiform or filiform,  $30-40 \times 2-3\ \mu$ .

*Entyloma ranunculi*, Schroeter, Pilze, Schles. p. 282; Sacc. Syll. vii. ii. n. 1793; Plow. Brit. Ured. and Ustilag. p. 290.

*Fusidium ranunculi*, Bon. Hdbk. Myc. p. 43.

*Glæosporium ficariæ*, Cke. Hdbk. p. 475.

On *Ranunculus repens*, *R. sceleratus*, *Ficaria ranunculus*. Common, especially on the last-named host.

*Entyloma Trailii*, Mass.

Spots on stems (irregularly rounded or oval), or more often on leaves, affecting the segments on all their surfaces, small, nearly white, while gonidia are being formed, but becoming brown and dry; gonidia (produced freely on gonidiophores pushed out in clusters from the stomata) fusiform or filiform,  $15-20 \times 1.5-2\ \mu$ , pale yellowish, pluriguttulate or faintly 3—4 septate; resting-spores abundantly formed in the tissues of the host, round or polygonal from pressure, 10-12  $\mu$  in diameter; epispore smooth, about  $1.5\ \mu$  thick, at first hyaline, becoming brown.

*Entyloma matricariæ*, Trail, in Plow. Brit. Ured. and Ustilag. p. 291.

On *Matricaria inodora*. Rare.

Apparently very closely allied to *Entyloma matricariæ*, Rostr. in Thum. Myc. Univ. n. 2223, but the gonidia in the latter are elliptical, and measure  $4.6 \times 2.2.5\ \mu$ .

B. *Formation of gonidia on the living host-plant not observed.*

*Entyloma chrysosplenii*, Schroet.

Sori forming spots 2—6 mm. broad, at first whitish, then pale yellow; resting-spores globose or broadly elliptical, 10-12  $\mu$  diameter, epispore thin, subhyaline, smooth.

*Entyloma chrysosplenii*, Schroeter, Cohn's Beitr. ii. p. 372; Sacc. Syll. vii. pt. ii. n. 1804; Plow. Brit. Ured. and Ustilag. p. 291.

*Protomyces chrysosplenii*, B. and Br. Ann. Nat. Hist. (1875), vol. xv. ser. 4, 36; Cke. Micr. Fung. ed. 4, p. 227.

On *Chrysosplenium oppositifolium*. Rare.

*Entyloma calendulæ*, De Bary.

Sori in rounded spots reaching to 4 mm. diameter, spots at first greenish or whitish, then pale brown; resting-spores globose or angularly globose, 9-16  $\mu$  diameter, epispore thin, smooth, pale yellow-brown; primary sporidia acicular.

*Entyloma calendulæ*, De Bary, Bot. Ztg. 1874, p. 105, t. ii. ff. 14—22; Plow. Brit. Ured. and Ustilag. p. 292.

*Protomyces calendulæ*, Oudem. Mat. Fl. Myc. Neerl. ii. p. 42.

*Protomyces hieracii*, Cooke, Grev. v. xii. p. 99.

On leaves of *Calendula officinalis*, *Hieracium murorum*, *H. vulgatum*. Rare.

*Entyloma microsporum*, Schroet.

Sori scattered or subgregarious, remaining under the cuticle, forming roundish or elongated, hard pustules, spots white, then yellowish or brown; rest-

ing-spores intercellular, often arranged in series,  $15-24 \times 12-18 \mu$ , irregularly globose, very pale yellow-brown, epispore  $3-6 \mu$  thick, stratose; primary sporidia cylindrico-fusoid, conjugating in pairs.

*Entyloma microsporum*, Schroeter, Pilze, Schles. p. 284; Plow. Brit. Ured. and Ustilag. p. 291; Sacc. Syll. vii. ii. n. 1810.

*Protomyces microsporus*, Unger, Exanth. p. 343.

*Entyloma ungerianum*, Cooke, Micr. Fung. ed. 4, p. 233.

On *Ranunculus repens*, *R. bulbosus*, *R. acris*. Not uncommon.

### **Melanotænium, De Bary.**

Sori flattened, expanded, black or greyish; resting-spores solitary, produced within the intercellular hyphæ, epispore thick, coloured; promycelium septate, sporidia apical.

*Melanotænium*, De Bary, Bot. Ztg. 1874; Sacc. Syll. vii. ii. p. 496; Plow. Brit. Ured. and Ustilag. p. 292.

#### *Melanotænium endogenum*, De Bary.

Sori flattened, black, covered by indurated epidermis; mycelium intercellular, spreading throughout the tissues of the host; resting-spores globose, angularly globose, or broadly elliptical, smooth, blackish brown, subopaque,  $15-22 \times 12-20 \mu$ ; promycelium usually with a sterile branch at the base, primary sporidiola cylindrical, conjugating in pairs and germinating at once.

*Melanotænium endogenum*, De Bary, Bot. Ztg. 1874, p. 108; Sacc. Syll. vii. ii. n. 1825; Plow. Brit. Ured. and Ustilag. p. 292.

*Protomyces endogenus*, Unger, Exan. p. 341.

*Protomyces Galii*, Rabh. in Fekl. Enum. Fung. Nass. n. 1.

On *Galium verum*. Rare.

Mycelium penetrating the whole of the host plant, intercellular, furnished with haustoria. The affected plants are much altered in appearance, the internodes are shorter, leaves crisped, and the bloom usually arrested.

### **Entorrhiza, C. Weber.**

Mycelium developing within the cells of living plants, resting-spores large, simple, produced at the tips of short, lateral branches, one or several formed in the cells of the host, epispore thick; on germination the resting-spores form one or several slender, septate, simple or sometimes slightly branched promycelium-tubes; sporidia falcate, formed at the apex of the promycelium, also laterally.

*Entorrhiza*, C. Weber, Bot. Ztg. 1884, p. 369; Sacc. Syll. vii. ii. p. 497; Plow. Brit. Ured. and Ustilag. p. 298.

The species of the present genus form small tubercular swellings in the roots of plants. The slender, curved primary sporidia are characteristic.

*Entorrhiza Aschersoniana*, De Toni (figs. 43, 44).

In the cells of living roots, resting-spores broadly-elliptical, clear brown, with numerous rather large, irregularly shaped warts on the epispore,  $15-17 \times 11-15 \mu$ ; promycelial tubes 1—4, very thin, rarely with one or two short branchlets, septate, primary sporidia slender, cylindric-fusiform, septate, scattered,



springing from the apex and laterally,  $7.9 \times 1.5-2 \mu$ .

*Entorrhiza Aschersonia*, De Toni, Sacc. Syll. vii. ii. n. 1828.

*Entorrhiza cypericola*, C. Weber, Bot. Ztg. 1884, p. 369, pl. iv.; Plow. Brit. Ured. and Ustilag. p. 299.

*Schinzia Aschersoniana*, Magnus, Bericht. Deutsch. bot. Gessel. vi. 2. 1888, p. 103, ff. 3, 4.

Forming swellings on the roots of *Juncus bufonius* and *J. lamprocarpus*. Rare.

The species mentioned by P. Cameron in Proc. and Trans. Nat. Hist. Soc. of Glasgow, new ser. v. ii. 1886, pp. 295-304, is probably *Entorrhiza casparyana*, De Toni (= *Schinzia casparyana*, Magnus, in Bericht. Deutsch. Bot. Gessel. vi. 2, 1888, p. 103).

### Doassansia, Cornu.

Spores in dense masses, of equal size, smooth, not forming spore-clusters, produced within a special receptacle formed of closely adnate sterile cells originating from the mycelium; on germination the resting-spores form a promycelium which bears sporidia at its apex.

*Doassansia*, Cornu, in Ann. Sci. Nat. (Bot.) 1883, p. 285; Sacc. Syll. vii. pt. ii. p. 502; Plow. Brit. Ured. and Ustilag. p. 294.

Agreeing with the genus *Sphacelotheca* in having a special receptacle formed of fungous elements, but distinguished by the absence of a columella and the different mode of origin of the primary sporidia.

*Doassansia alismatis*, Cornu (figs. 118, 119).

Spore-clusters on both surfaces of the leaves,

minutely prominent, brown, up to  $300\ \mu$  diameter, globose or elliptical, rarely irregular, numerous, seated on yellowish spots that are for the most part determinate and orbicular, 4—10 mm. long, rarely subconfluent and circinately arranged; resting-spores globose, broadly elliptical, or angularly globose,  $10\text{--}14 \times 8\text{--}11\ \mu$ , sometimes larger, epispore thin, smooth, pale brown; primary sporidia elongate cylindrical, numerous, springing from the apex of the promycelium; general integument of spore-cluster well developed, cellular, brown.

*Doassansia alismatis*, Cornu, Sur quelques Ustilaginées nouvelles ou peu connus, Ann. Sci. Nat. ser. vi. vol. xv. (1883) p. 285, t. xvi. ff. 1—4; Sacc. Syll. vii. pt. ii. n. 1842; Plow. Brit. Ured. and Ustilag. p. 294.

*Entyloma alismacearum*, Sacc. in Michelia, v. ii. p. 44.

In leaves of *Alisma plantago*. Rare.

Often found along with *Cylindrosporium alismacearum*, Sacc., with which it is considered to be genetically connected.

*Doassansia sagittariæ*, Fischer.

Spore-clusters pustulate, on the under surface of the leaves, numerous, sometimes more or less confluent, spots yellowish, centre darker, on both surfaces of the leaf, 5—10 mm. across; spore-clusters globose or irregular, yellow-brown, up to  $100\ \mu$  diameter; resting-spores globose or angularly globose, epispore rather thick, smooth, yellowish,  $9\text{--}14 \times 9\text{--}12\ \mu$ ; primary sporidia elongate cylindrical, nume-

rous, produced at the apex of the promycelium; general investment of spore-clusters well developed, brown.

*Doassansia sagittariæ*, Fischer, in Berichte Deutsch. botan. Gesell. ii. p. 405 (1884); Sacc. Syll. vii. ii. n. 1842; Plow. Brit. Ured. and Ustilag. p. 295; Cke. Micr. Fung. ed. 4, p. 227.

*Physoderma sagittariæ*, Fckl. Fung. Rhen. n. 1549.

On *Sagittaria sagittifolia*. Not common.

*Doassansia comari*, De Toni and Mass.

Sori gregarious or scattered, blackish when dry, 1—1.5 mm. diameter; resting-spores broadly elliptical,  $10 \times 7 \mu$ , smooth, pale brown with vinous tinge; general integument of spore-clusters well developed, cellular, brown.

*Doassansia comari*, De Toni and Massee, revis. of *Doassansia* in Journal of Mycology, 1888, p. 18; Sacc. Syll. vii. ii. n. 1852.

*Protomyces comari*, Berk. Ann. Nat. Hist. n. 1708; Sacc. Syll. vii. i. n. 1135.

On leaves of *Comarum palustre*. Rare.

Forming gregarious or scattered, usually elongated pustules on both surfaces of the leaves.

### **Tuburcinia, Fries.**

Sori black, flattened or slightly bullate, often broadly expanded; resting-spores of uniform size, aggregated in clusters; germination by the formation of a slender promycelium which forms primary sporidia

at the apex; gonidial condition originating from mycelium in the living host-plant, white, forming expanded tufts; gonidia elliptical.

*Tuburcinia*, Fries, Syst. Myc. iii. p. 430; Sacc. Syll. vii. pt. ii. p. 507.

*Tuburcinia*, Plow. Brit. Ured. and Ustilag. p. 293.

Resembling *Sorosporium* in having the resting-spores of uniform size and structure aggregated in clusters, but differs in the absence of a gelatinous integument surrounding the spore-clusters.

*Tuburcinia trientalis*, B. and Br. (figs. 112—115).

Sori 3—4 mm. broad, black, bullate, for some time covered by the epidermis; spore-clusters globose, elliptical, or irregular, composed of from 50—100 resting-spores, 40-120  $\mu$  diameter; resting-spores globose, elliptical, often irregularly compressed by mutual pressure, 15-32  $\times$  10-17  $\mu$ , epispore smooth, obscure brown, semipellucid; primary sporidia numerous, produced at the apex of the promycelium, cylindrical-fusoid, conjugating in pairs towards the base and bearing fusiform, secondary sporidia; gonidia colourless, elliptical or obpyriform.

*Tuburcinia trientalis*, B. and Br. Ann. Nat. Hist. (1850) n. 488; Sacc. Syll. vii. pt. ii. n. 1853.

*Tuburcinia trientalis*, Plow. Brit. Ured. and Ustilag. p. 293.

*Ascomyces trientalis*, Berk. Outl. p. 376; Cke. Hdbk. p. 516 (gonidial condition).

*Sorosporium trientalis*, Woronin, Cke. Micr. Fung. ed. 4, p. 231.

On the stem and leaves of *Trientalis europæa*. Rare.

Forming crust-like expansions on the stem and irregularly rounded spots on the leaves; gonidial condition forming white, effused patches on the under surface of the leaves, gonidiophores slender, erect, originating from mycelium in the tissues of the leaf, and passing into the air either through the stomata or between the epidermal cells. The life history of the present species is worked out and beautifully illustrated by Woronin, *Beitrag. zur Kenntniss der Ustilagineen*.

### **Thecaphora**, Fingerh.

Spore-clusters composed of resting-spores of equal size and firmly adherent, difficult to separate without rupturing, free portion of surface convex, lateral contiguous portions flattened; promycelium filiform, sometimes with short lateral branches, primary sporidia fusoid, solitary at apex of promycelium.

*Thecaphora*, Fingerhuth, in *Linnaea*, x. (1835), p. 230; Sacc. *Syll.* vii. pt. ii. p. 507; Plow. *Brit. Ured.* and *Ustilag.* p. 295.

Agreeing with *Sorosporium* in having all the resting-spores of the spore-cluster fertile and of equal size, but in *Sorosporium* the resting-spores are very numerous, small, and spherical, and easily fall apart, in the present genus the resting-spores are firmly adherent to each other, the surfaces in contact flattened, the free portion convex.

*Thecaphora hyalina*, Fingerh. (figs. 88, 89, 111).

Produced within the seeds of the host, sori pale reddish-brown, coarsely pulverulent; spore-masses irregularly globose, very variable in size, 25-50  $\mu$

diameter, composed of from 3—12 firmly cohering resting-spores of a pale brown colour, more or less wedge-shaped, free external portion convex, thickly covered with warts, inner faces flat, smooth, 12-17  $\mu$  diameter; promycelium branched; sporidiola unknown.

*Thecaphora hyalina*, Fingerh. in Linnæa, x. p. 230; Sacc. Syll. vii. ii. n. 1855; Plow. Brit. Ured. and Ustilag. p. 295; Cke. Hdbk. p. 515; Cke. Micr. Fung. ed. 4, p. 231.

On *Convolvulus soldanella*, *C. sepium*, *C. arvensis*.  
Not common.

*Thecaphora Trailii*, Cooke (figs. 94, 95).

Produced in the inflorescence, becoming coarsely pulverulent; spore-clusters variable in size, umber-brown, resting-spores subglobose or compressed at the points of contact, epispore with delicate, slightly raised bands anastomosing to form a more or less regular, small-meshed network, 12-16  $\mu$  diameter.

*Thecaphora Trailii*, Cooke, Grev. vol. xi. p. 155; Plow. Brit. Ured. and Ustilag. p. 296; Sacc. Syll. vii. pt. ii. n. 1867.

On *Carduus heterophyllus*. Rare.

The epispore is minutely but very distinctly reticulated, and not verrucose as described by Cooke.

### Sorosporium, Rud.

Resting-spores of uniform size, small, all fertile, at first in dense spore clusters, but not compact, and soon breaking up, produced by tufts of intertwined hyphæ that become gelatinized, the entire spore-

cluster at first involved in a gelatinous integument; promycelium filiform, sporidia unknown.

*Sorosporium*, Rudolphi in Linnæa, iv. (1829), p. 116; Sacc. Syll. vii. pt. ii. p. 511; Plow. Brit. Ured. and Ustilag. p. 296.

Readily distinguished by the dense spore-clusters consisting of numerous small resting-spores of equal size and functional value.

The true position of the present genus is somewhat uncertain owing to imperfect knowledge in respect to the formation of the primary sporidia.

*Sorosporium saponarice*, Rud. (figs. 109, 110).

Sori pale rufous-brown, becoming coarsely pulverulent, produced in the inflorescence during the bud stage; spore-clusters subglobose or elliptical, 40-100  $\mu$ , consisting of numerous resting-spores loosely coherent; resting-spores globose, broadly elliptical, or irregularly angular from mutual pressure, ochraceous, the free side covered with minute warts or irregular, elongated ridges,  $18 \times 10-14 \mu$ ; promycelium filiform.

*Sorosporium saponariæ*, Rudolphi, Linnæa, iv. (1829), p. 116; Sacc. Syll. vii. ii. n. 1872; Plow. Brit. Ured. and Ustilag. p. 296.

In the flowers (ovary, stamens, &c.), rarely the uppermost leaves of *Dianthus deltoides*, *Saponaria officinalis*, *Silene inflata*. Rare.

*Sorosporium scabies*, Fisch. de W. (figs. 59, 59a).

Sori forming large, olive, scab-like expansions; spore-clusters globose or elliptic-oblong, the resting-

spores forming a hollow sphere with the wall irregularly perforated here and there, 20-50  $\mu$  diameter; resting-spores firmly agglutinated together, spherical or subangular, smooth, pale olive or brownish, 4-5  $\mu$  diameter.

*Sorosporium scabies*, Fischer de Waldheim, Aperçu, p. 33; Sacc. Syll. vii. ii. n. 1879.

*Tubercinia scabies*, Berk. Journ. Roy. Hort. Soc. 1846, v. i. p. 33, figs. 30—31; Plow. Brit. Ured. and Ustilag. p. 294; Cke. Hdbk. p. 516; Cke. Micr. Fung. t. iii. p. 54.

(Type in Herb. Berk., Kew.)

On potato tubers.

The spore-clusters are very peculiar resembling in miniature the young, partly expanded receptacle of *Clathrus cancellatus*.

## APPENDIX.

Species considered by some authors as showing affinity with the *Ustilagineæ*.

### **Tuberculina, Sacc.**

*Sporodochium* minute, plano-pulvinate, often more or less violet, at length becoming indurated and sclerotiform; gonidia globose or nearly so, acrogenous, gonidiophores rather thick, simple or with a few short branchlets.

*Tuberculina*, Saccardo, Michela, vol. ii. p. 34 (April, 1880); Plow. Brit. Ured. and Ustilag. p. 299; Sacc. Syll. vol. iv. p. 653.

*Uredinula*, Speg. Fung. Argent. Pug. ii. p. 15 (May, 1880).



The species, twelve in number, have a wide distribution, and are parasitic on fungi belonging to the *Uredineæ*. The general habit is that of a *Tubercularia*, near to which form-genus it has been arranged by Saccardo. C. Gobi, on the other hand, considers the genus as having more affinity with the *Ustilagineæ*.<sup>6</sup>

*Tuberculina persicina*, Sacc. (figs. 132).

Sporodochium globuloso-depressed, minute, often arranged concentrically, violet-brown, paler inside; gonidia subglobose, 7-8  $\mu$  rarely 10  $\mu$  diameter, rosy-violet, smooth; gonidiophores simple or with a few scattered branchlets, aseptate, denticulate at apices, subhyaline.

*Tuberculina persicina*, Saccardo, Fung. Ital. t. 964; Sacc. Syll. vol. iv. n. 3088; Plow. Brit. Ured. and Ustilag. p. 299 (exclusive syn. *Tuberculina vinosa*, Sacc.).

*Tubercularia persicina*, Ditm. in Sturm. t. 49.

Parasitic on *Uredo*, *Æcidium*, and *Roestelia* stages and various *Uredines*. Not common.

*Tubérculina vinosa*, Sacc.

Closely allied to *Tuberculina persicina*, Sacc., from which it differs in the larger pustules of a vinous colour; gonidia subglobose or ovoid, 11-12  $\times$  10  $\mu$  (not 7-8  $\mu$  diam.), gonidiophores shorter, thicker, septate, simple.

*Tuberculina vinosa*, Sacc. Michelia, i. p. 262, and

<sup>6</sup> Acad. Imp. des Scienc. de St. Petersburg, ser. vii., vol. xxxi. (1884).

ii. p. 34; Fung. Ital. t. 963; Sacc. Syll. vol. iv. n. 3089.

Parasitic on *Æcidium*, on *Tussilago farfara*, on *Roestelia*, on leaves of *Pyrus* and *Cratægus*, and on *Æcidium* on boraginaceous plants. Rare.

### **Graphiola, Poit.**

Erumpent; peridium minute, wall double, outer firm, composed of blackish, interlaced hyphæ, inner pale, delicate, fertile hyphæ springing from base of peridium, crowded, septate, producing spores laterally; after the formation of the spores agglutinated bundles of slender, elongated, viscid hyphæ spring up between the fertile hyphæ and carry up the spores outside the peridium; the spores on germination give origin to a slender, septate, branched mycelium, or to slender, cylindrical sporidia.

*Graphiola*, Poiteau, Ann. Sci. Nat. (Bot.), 1824, p. 473, t. xxvi. fig. 2; Sacc. Syll. vii. ii. p. 522; Plow. Brit. Ured. and Ustilag. p. 297.

*Graphiola phœnicis*, Poit. (figs. 133, 134).

Erumpent; perithecia hard, blackish externally, 1—2 mm. diameter, spores pale yellow, 5-6  $\mu$  diameter, sterile dispersive hyphæ yellow, forming a plume-like tuft protruding for 2—3 mm. beyond the perithecium.

*Graphiola phœnicis*, Poiteau, Ann. Sci. Nat. 1824, p. 473, t. 26, f. 2; Cke. Hdbk. p. 546; Plow. Brit. Ured. and Ustilag. p. 298; Sacc. Syll. vii. ii. n. 1915.

*Phacidium phœnicis*, Mont. in Fries' Syst. Myc. ii. p. 372.

On leaves of *Phoenix dactylifera* and *Chamærops humilis*, in conservatories.

*Schinzia leguminosarum*, Frank.

The presence of tubercles varying in size from 1 mm. to 1 cm. or more have for a long time been known to occur on the roots of many leguminous plants, in fact these swellings are so common that it is a difficult matter to find a specimen of the ordinary leguminous plants, as peas, beans, vetches, the roots of which are free from such tubercles. A curious feature is that although considerable attention has been paid to these malformations, no one has succeeded in showing that their presence is in any way injurious to the plant. Various opinions have been entertained as to the cause of these tubercles, the component cells of which are abnormally large and contain myriads of very minute corpuscles of variable form, considered by some authors as of a bacterioid nature, by others as approaching the genus *Plasmodiophora*, a myxomycete causing the tubercular swellings known as "fingers and toes" on turnip roots. Professor Marshall Ward has demonstrated the presence of hyphæ in these swellings, and also considers the hyphæ to originate from the germination of one of the minute corpuscles present in the abnormally large cells, and the same author further considers that in all probability the corpuscles are produced in immense numbers from the blind, more or less tufted ends of hyphæ penetrating the cells. It is clear from the description given that the organism cannot belong either to the *Bacteria* or the *Myxogastres*. Ward's

own idea as to its affinity is expressed as follows: "I regard the fungus as one of the Ustilagineæ, which has become so closely adapted to its life as a parasite in the roots of the Leguminosæ that it has come to stimulate and tax its host in an exquisitely well-balanced manner, and has lost its needless true resting-spores because the more numerous and tiny sprouting yeast-cells (gemmules) are kept in the cells of the tubercle through the dry summers and autumn, and freed during the rotting in the soil in the winter and spring. Their very minuteness and numbers enable these 'germs' to become as ubiquitous as 'Bacteria' or ordinary 'yeast' forms, thus explaining the ubiquity of the tubercles."<sup>7</sup>

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## FOSSIL FUNGI.

*Protomycites protogenes*, W. Sm. (fig. 135). Mycelium very scanty,  $18\ \mu$  thick; oogonium spherical, about  $200\ \mu$  diameter, oospore solitary,  $130\ \mu$  diameter.

*Protomycites protogenes*, W. Sm., in Diseases of Field and Garden Crops, p. 333, fig. 140.

In a slice from a rootlet of a fossil *Lepidodendron* from the coal-measures.

We have a second representative of fungi of enormous antiquity in a transparent silicified slice of a rootlet of *Lepidodendron* from the coal-measures, now in the British Museum at South Kensington. This slice exhibits numerous unusually large sporangia of a fungus not to be distinguished from *Protomyces*. Very little mycelium can be detected, and many of the sporangia of the fungus are situated in positions where the tissues of the host plant have apparently, but perhaps not really, decayed. We have illustrated one sporangium of this fungus, which may be named *Protomycites protogenes*, W. Sm., at fig. 140, enlarged 400 diameters (*protogenes*, first produced or primæval). In most of the silicified examples an outer, or exospore, and inner, or endospore, are distinctly visible. (Worthington G. Smith, l.c.)

It is uncertain as to whether the above structures

should be considered as resting-spores or oospores with a very thick wall, or whether the outer wall is that of an oogonium containing a single oosphere. As to their fungoid nature and also their close resemblance to the *Phycomycetes* there can be no reason for doubt.

*Peronosporites antiquarius*, W. Sm. (fig. 136). Mycelium with numerous tranverse septa, 7-9  $\mu$  thick, variously branched; oogonia usually terminal on short branches, rarely intercalary, globose or slightly attenuated at the base, 40-60  $\mu$  diameter.

*Peronosporites antiquarius*, W. Sm., Gard. Chron., with fig., Oct. 20th, 1877; Diseases of Field and Garden Crops, p. 331, with fig.

Mr. Carruthers, F.R.S., of the British Museum, also gave a brief description of the fungus, accompanied by a small figure in his printed address, read before the Geologists' Association in 1876.

Williamson in Phil. Trans. Roy. Soc., vol. clxxii., part ii., p. 299, pls. 48 and 54?

In the vascular axis of *Lepidodendron*, lower coal-measures, West Yorkshire.

Professor Williamson has the following remarks on the present species:—

“Some years ago Mr. Carruthers found a fossil fungus in a fragment of a *Lepidodendron* from the lower coal-measures of West Yorkshire, of which he gave a brief account in his annual address to the Geologists' Association for 1876. Mr. Butterworth, of Oldham, found a second example, which was described and figured by Mr. Worthington Smith in the *Gardener's Chronicle* for October 20, 1877, under the name of *Peronosporites antiquarius*. Mr. Smith

figures and describes the hyphæ of the fungus as having septa, and its supposed oogonia as containing zoospores. The existence of these zoospores was denied by Mr. Murray, of the British Museum, in the *Academy* for November 17, 1877. Still more recently another example of the plant has been met with at Halifax in the cabinet of Mr. Spencer. Fragments of Lepidodendroid bark, the cells of which are filled with fragmentary hyphæ, but with few traces of oogonia, also from Halifax, are in the cabinet of Mr. Cash. I have had the opportunity of examining all these specimens with the exception of that in Carruthers' cabinet, which example he informs me is a very imperfect one compared with those more recently discovered.

"I have failed to find any traces of septa in the hyphæ of this plant, and I quite agree with Mr. Murray in his opinion that no zoospores exist in any of them. Some of the oogonia contain black coaly matter, such as is frequently found in the ordinary cellular tissues of carboniferous plants; but I believe this to be the result of infiltration, since I find it extended into the hollow tubes of some of the hyphæ, and is not confined to the oogonia themselves. Having examined the actual specimen described and figured by Mr. Smith with the aid of a Zeiss oil-immersion lens, I have no hesitation in arriving at the same conclusion as Mr. Murray has done, viz. that its oogonia contain no zoospores. The plant has been an unicellular branching mycelium with numerous dilatations on the branching hyphæ, which dilatations seem to have been oogonia. No septal division separates

the cavities of these oogonia from the hollow hyphæ prolonged from them. Mr. Smith came to the conclusion that since the fossil fungi which he described possessed, as he believed, septate hyphæ and oogonia containing oospores, they must be ranked with the *Peronosporæ*. I confess that I cannot confirm the alleged facts nor accept the inference drawn from them. That the plant is a fungus seems most probable; equally so that its relations are with the *Saprolegniæ*. The discovery of its reproductive organs in a more perfect state will alone enable us to arrive at a perfectly satisfactory conclusion on this point.”<sup>8</sup>

Professor Williamson has given figures of the fungus he considers to be identical with Smith's *Peronosporites antiquarius* from various localities of the lower coal-measures of West Yorkshire, occurring mostly in fragments of Lepidodendroid bark. Fig. 137 of the present work is copied from Professor Williamson's drawings.

Mr. W. G. Smith replies as follows to Williamson's remarks given above:—

“Notwithstanding criticisms to a contrary effect, we have no hesitation in repeating, after a renewed and prolonged examination of the preparation, that traces of zoospores are distinctly visible in many of the oogonia; there is no reason why they should not exist, but good reason why they should; the mycelium is septate, and the oogonia, as in all *Peronosporæ* and *Saprolegniæ*, are cut off from the supporting threads by distinct septa.”<sup>9</sup>

<sup>8</sup> Phil. Trans. Roy. Soc., vol. clxxii., pt. ii., p. 299, pls. 48 and 54.

<sup>9</sup> Diseases of Field and Garden Crops, p. 331.

Remembering the great difficulty experienced in distinguishing so-called species of *Saprolegnia* even in the living state from purely morphological characters, or even distinguishing between the genera *Saprolegnia* and *Peronospora* when sexual portions alone are present, from the same characters it can be readily understood that the difficulties must be greatly increased when dealing with fragmentary fossil remains. It is doubtful whether the fungus under consideration was not better placed by Smith in the *Peronosporæ* than by Williamson in the *Saprolegniæ*. Members of the latter group do not as a rule produce their oogonia in tissues, whereas this is usual in the *Peronosporæ*. It is not usual for septa to be entirely absent, especially at the base of the oogonia, as believed to be the case by Professor Williamson in his specimens, which after all may be distinct from Smith's fungus.

Several other species of fungi apparently belonging to the *Phycomycetes* have been described as occurring in the tissues of fossil plants.

Mr. Carruthers has described the mycelium of a fungus resembling *Peronospora* found in the tissues of a fossil fern, *Osmundites Dowkeri*, Carr., from the lower Eocene of Herne Bay. Other forms are described by Cash in a paper entitled, "On the Fossil Fungi from the lower Coal-measures of Halifax," read before the Yorkshire Geological and Polytechnic Society in 1879.

## ADDENDA.

THE following species have unfortunately been omitted from their proper places :—

*Saprolegnia elongata*, Mass. (n. sp.), (figs. 47—49).  
 Diceceous; a sexual form very much elongated when fully developed, main stem slender, 3-4  $\mu$  thick, often flexuous, first zoosporangium terminal, elliptical, 50-60  $\times$  18-21  $\mu$ , filled with zoospores which escape from an opening at the apex; when the zoospores have escaped from the first zoosporangium the transverse septum at its base develops into a second zoosporangium which is elevated on a stem out of the first zoosporangium, in this way numerous superposed sporangia are produced; sometimes two new zoosporangia originate from the base of an old zoosporangium, thus producing a lateral branch; sexual form with the stem unbranched or with very short lateral branches terminated by oogonia that are globose, imperforate, 45-50  $\mu$  diameter, oospheres 3—4; antheridia elliptic-oblong, 30  $\times$  10  $\mu$ , supported on slender, flexuous branches, 3—4 of which originate from near the apex of the main stem, which with that supporting the oogonia are about 10  $\mu$  in diameter.

On decaying trunk of tree-fern in a tank. Rare.

The above species, which has occurred for two years in succession at Kew, I do not find to agree with any

described species. The plant producing zoosporangia was not found in organic connection with the sexual form, the relationship between the two being assumed entirely on the constant occurrence of the two forms. I have seen a specimen bearing forty-five zoosporangia arranged on a main stem as shown in fig. 47, and in addition also were several shorter lateral branches.

*Saprolegnia philomukes*, W. Sm. Mycelium stout, 7-10  $\mu$  diameter, with numerous transverse septa, the branches often connected by short transverse branches and forming H-shaped structures, sometimes more or less flexuous; zoosporangia numerous, intercalary, or more frequently terminating short branches, globose, 50-70  $\mu$  diameter, containing zoospores, which often germinate *in situ*; antheridia elliptic oblong; the mycelium in addition bears many small abortive sporangia or conidia on short lateral branches, normally colourless, but often becoming rose-coloured from absorbing the red colour of the host.

*Saprolegnia philomukes*, W. Sm. in Diseases of Field and Garden Crops, p. 67, fig. 24.

Parasitic on *Isaria fuciformis*. Rare.

It is doubtful whether the present species is a good *Saprolegnia* as at present understood. If the small bodies contained in the large vesicles are true zoospores it is not likely that the bodies called antheridia by Smith are in reality such. The following is Smith's further account of the organism:—

“Towards the end of 1883, Mr. Greenwood Pim, M.A., F.L.S., and Dr. E. P. Wright, A.M., F.L.S., detected *Isaria fuciformis*, B., growing in a new position, viz. on grass belonging to a silo at the Albert

Model Farm, Glasnevin, county Dublin. Mr. Pim kindly forwarded examples to us, and he soon afterwards published an illustrated account of the discovery in the *Gardener's Chronicle* for 22nd December, 1883. Mr. Pim's examples were remarkable for being infested with a parasitic fungus, and one apparently till now undescribed. The parasite grows on the *Isaria*, breaks up its tissues, and more or less absorbs its crimson colour. The parasite is a *Saprolegnia* allied to *S. ferox*, Kutz., of the salmon disease, but different in many important characters."

The new parasite, which may be termed *Saprolegnia philomukes*, W. Sm., is illustrated at fig. 24, enlarged 400 diameters. The circular bodies are sporangia, zoosporangia, or spore-cases of unusually large size and filled with small motile spores or zoospores. In the largest sporangium illustrated the zoospores are germinating within the sporangium, and protruding their germ-tubes through its gelatinous wall. A remarkable character in this parasite is found in the septate or jointed mycelium, an unusual character in the *Saprolegniæ*, in the mycelium carrying numerous conidia, and in the sporangia and mycelial threads often becoming confluent.

In the Dublin examples the sporangia were so abundant that all parts of the *Isaria* threads were covered, they were so crowded together that they took pentagonal and hexagonal instead of circular forms. Many sporangia were sessile, or intercalated in the mycelium, whilst others were shortly stalked. Anthecidia were rare. The jointed mycelium formed a dense transparent stratum over the host plant. In some



places the parasite was colourless, like the better known species of *Saprolegniæ*; in other places it was rose-coloured, from its absorbing the colour of the red *Isaria*. (Smith, l.c.)

*Protomyces concomitans*, Berk. (fig. 90). Spores globose, terminal, pale umber, wall thick; mycelium thin, septate, here and there colourless.

*Protomyces concomitans*, Berk. Gard. Chron. vol. xviii. p. 397, fig. 63 (1882).

Numerous specimens have occasionally been forwarded to us of a disease which has perplexed cultivators of orchids as much as the notorious cucumber pest has almost every gardener in the kingdom, and which have in both cases elicited much interesting information, though unfortunately it appeared after all that the disease was inscrutable, if that were any real satisfaction. There are two forms which appeared on orchid leaves, known under the name of black spot, one of which often comes over with imported orchids, and which evidently commenced while the plants were still in their native country. This was comparatively slow in its progress, though it too often proved in the end fatal. The other was paler in colour, but more speedy in action, and was altogether moister, and it is to this we now call attention. A small leaf of a *Dendrobium* was lately sent to us which called to mind a matter to which some years since we devoted much time, though without success. Instructed previously by what had been written by De Bary and others, we at once examined the leaf, and at first we found an immense quantity of aleurone (a proteinous matter) under most of the forms

figured by Hartig in a paper translated from the *Botanische Zeitung in Annales des Sc. Naturelles*, ser. iv., vol. vi., and especially the very curious form represented in fig. 7, i., ii. Mixed with these were abundant globose pale umber bodies, which we supposed to belong to a species of *Protomyces*, but as they were without any trace of mycelium or connection with hyphæ we felt rather doubtful. However, a fortunate thin slice brought into view abundant mycelium, with infant sporangia, besides others which were perfect and connected still with the fertile threads. A comparison of our figure (fig. 63) with those of De Bary in *Beiträge*, No. 1, 1864, will at once show that we have before us an allied production for which we propose the name of *Protomyces concomitans*. Our figure represents dark spores quite free, and others still adhering to the fertile threads, besides abundant mycelium passing beyond the cellular tissue, and sometimes immediately under the true cuticle. In one spore there is a distinct margin. (Berk.)

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#### EXCLUDED SPECIES.

- Peronospora exigua*, W. Sm.=*Ovularia*.
- Peronospora elliptica*, W. Sm.=*Ovularia*.
- Peronospora interstitialis*, B. & Br.=*Ovularia*.
- Peronospora rufibasis*, B. & Br.=*Ovularia*.
- Peronospora obliqua*, Cke.=*Ovularia*.



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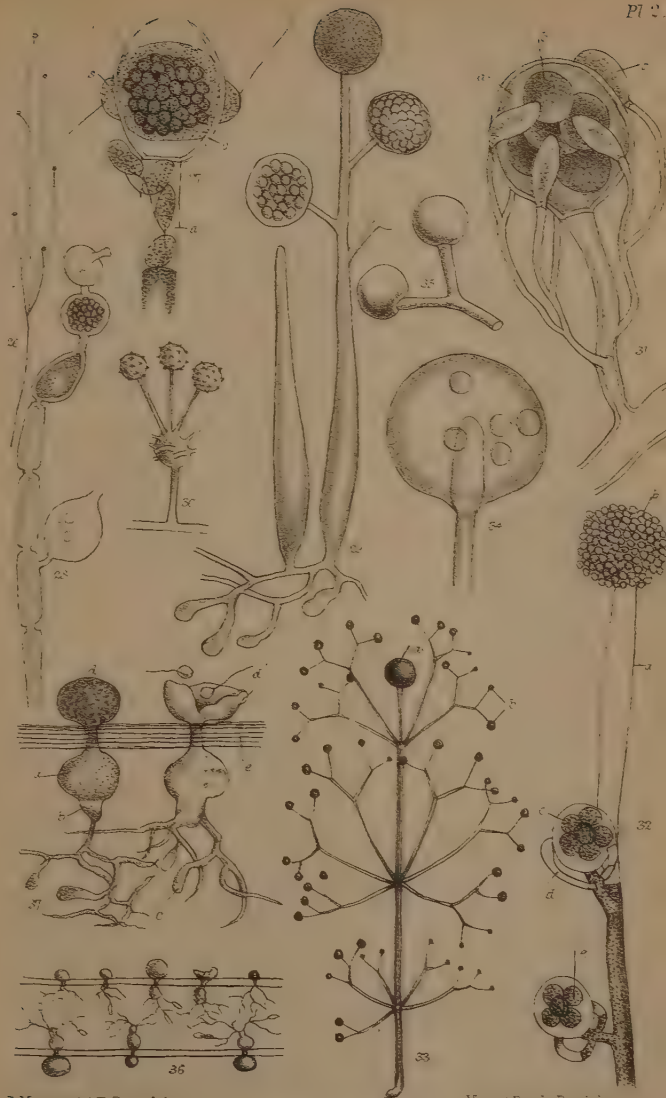
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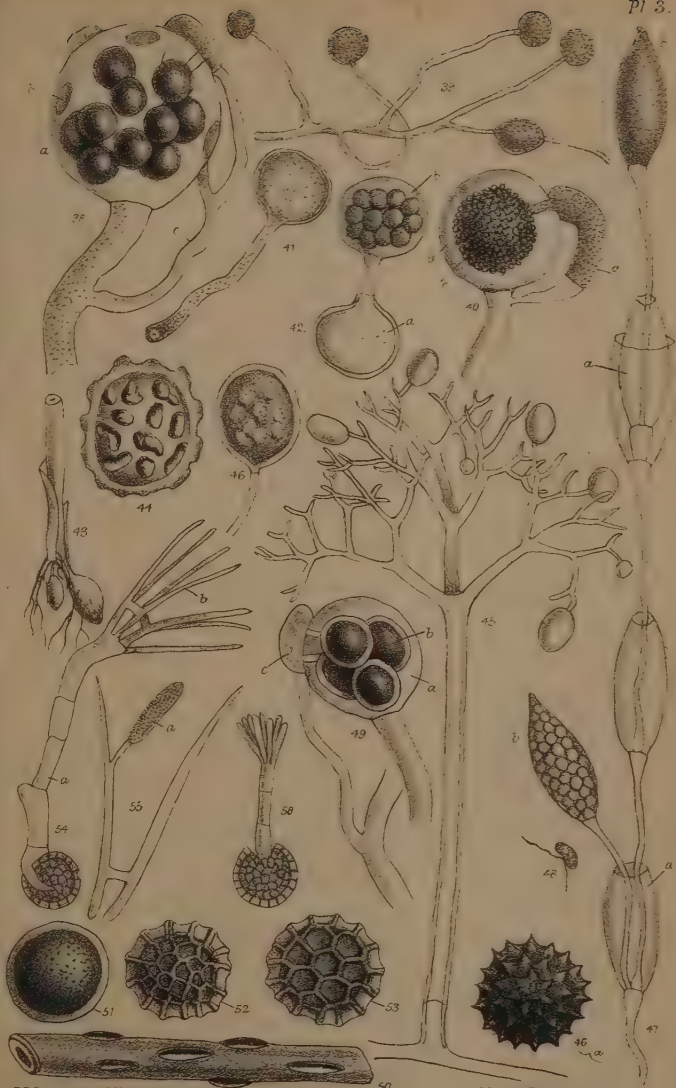


















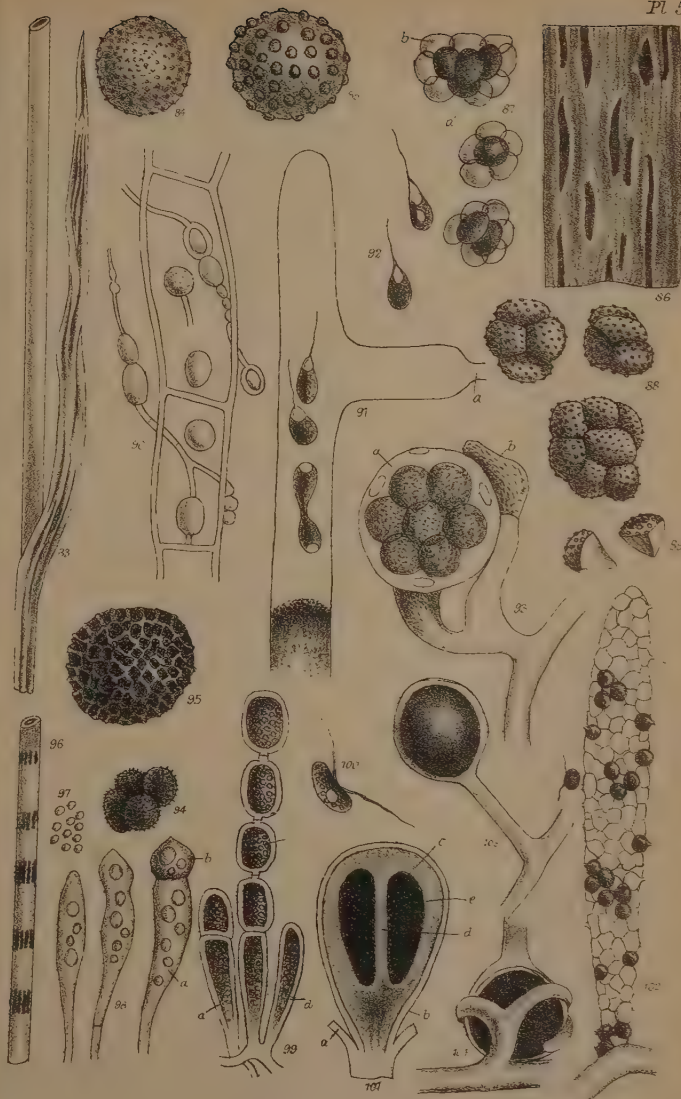














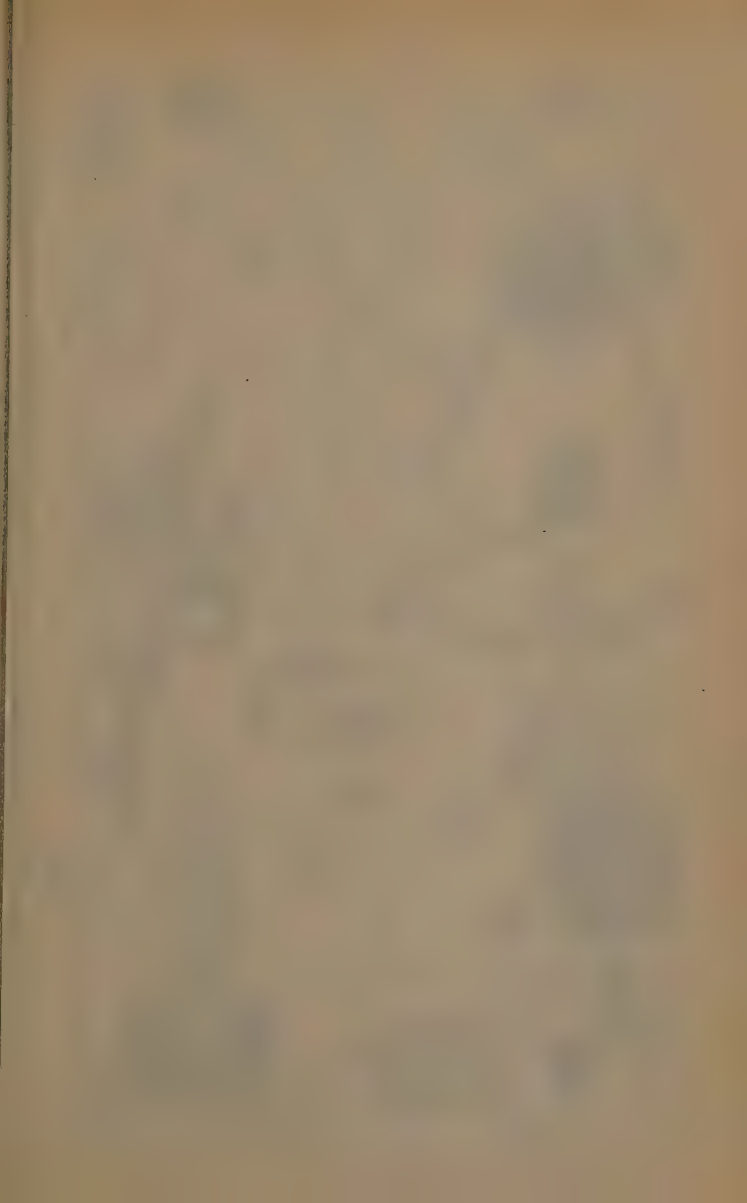








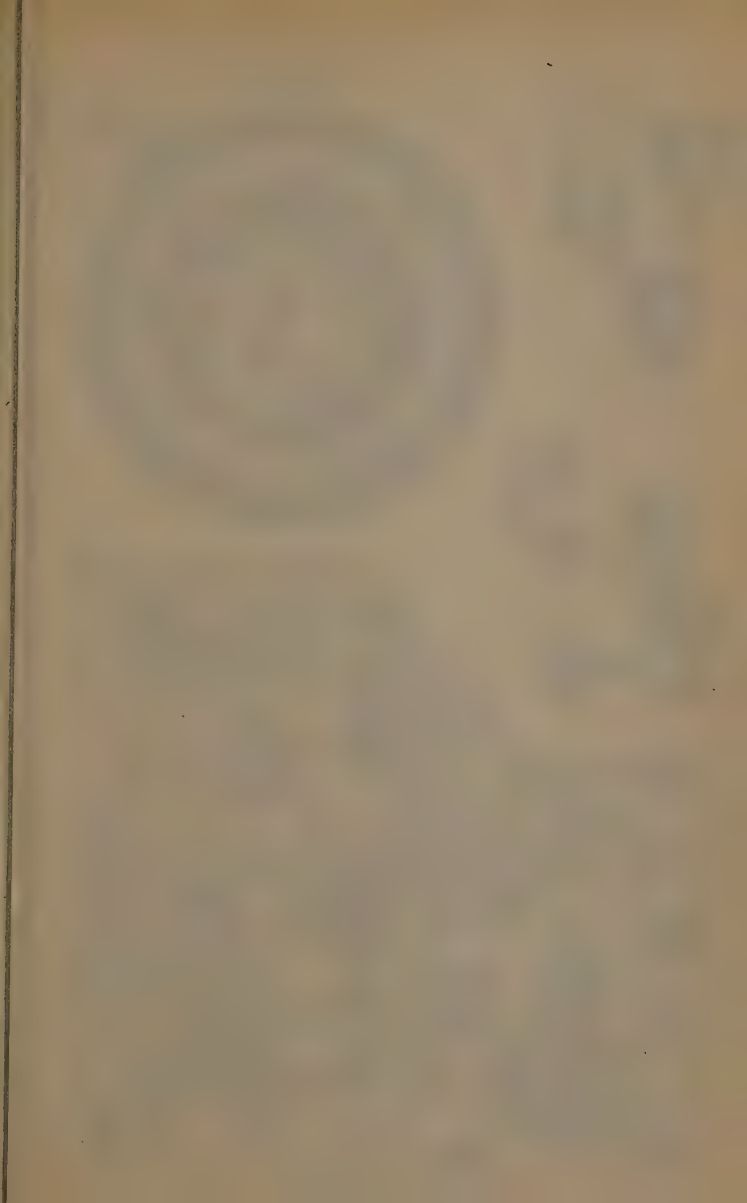




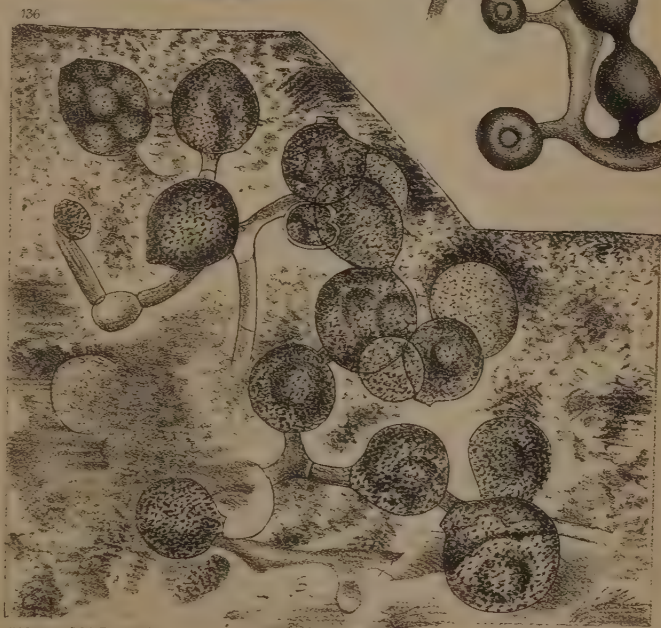
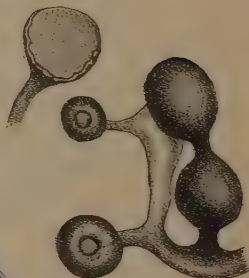




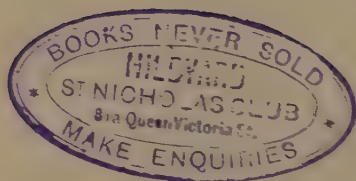












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